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# Electronic Engineering

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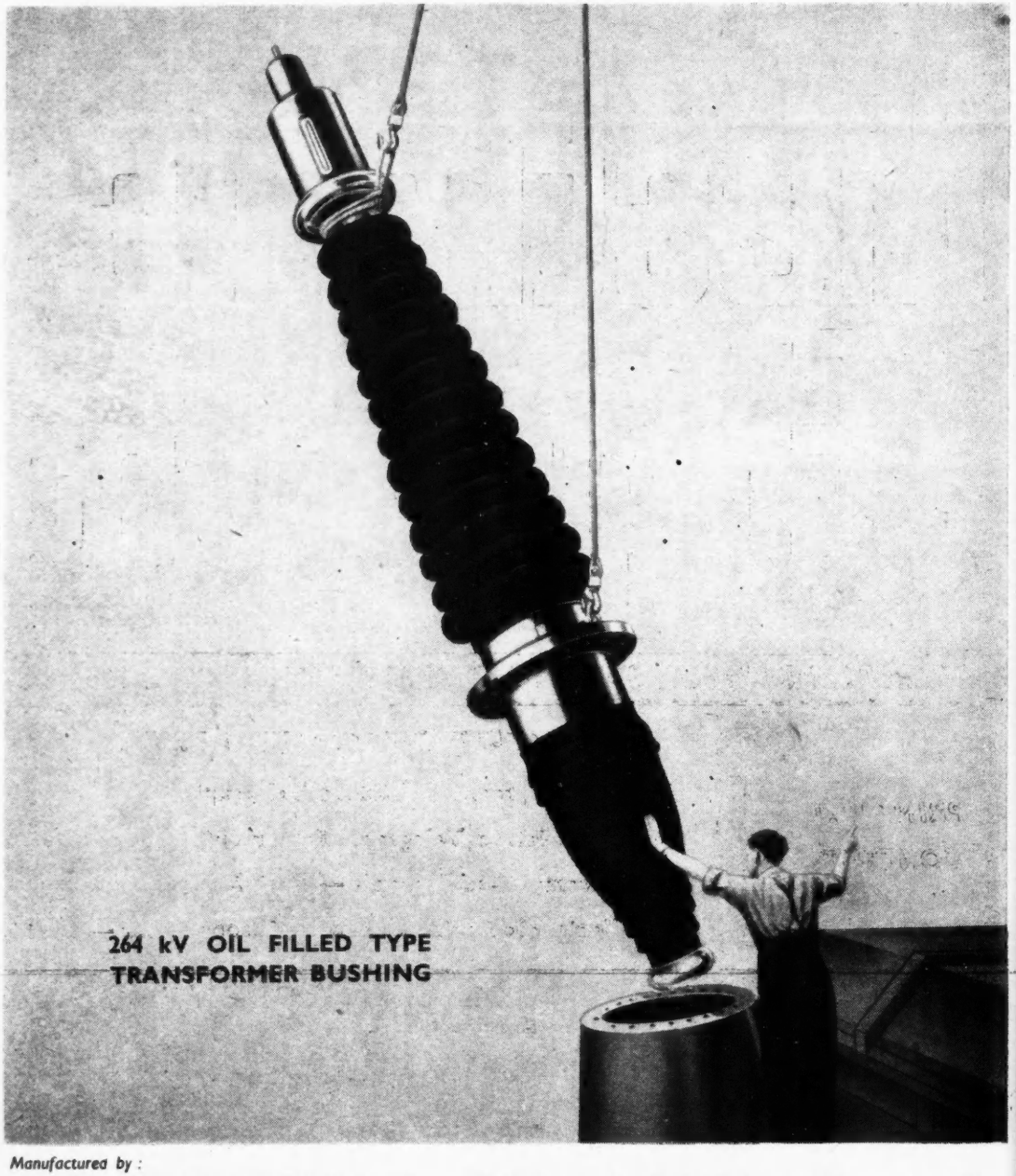
*PICTURE TELEGRAPHY NUMBER*

*PRINCIPAL CONTENTS*

The Development of Picture Telegraphy
Modern Picture Telegraph Equipment
A Universal Oscillograph — Part 2
An Electronic Decimal Counter Chronometer — Part 2

2/- FEB., 1947

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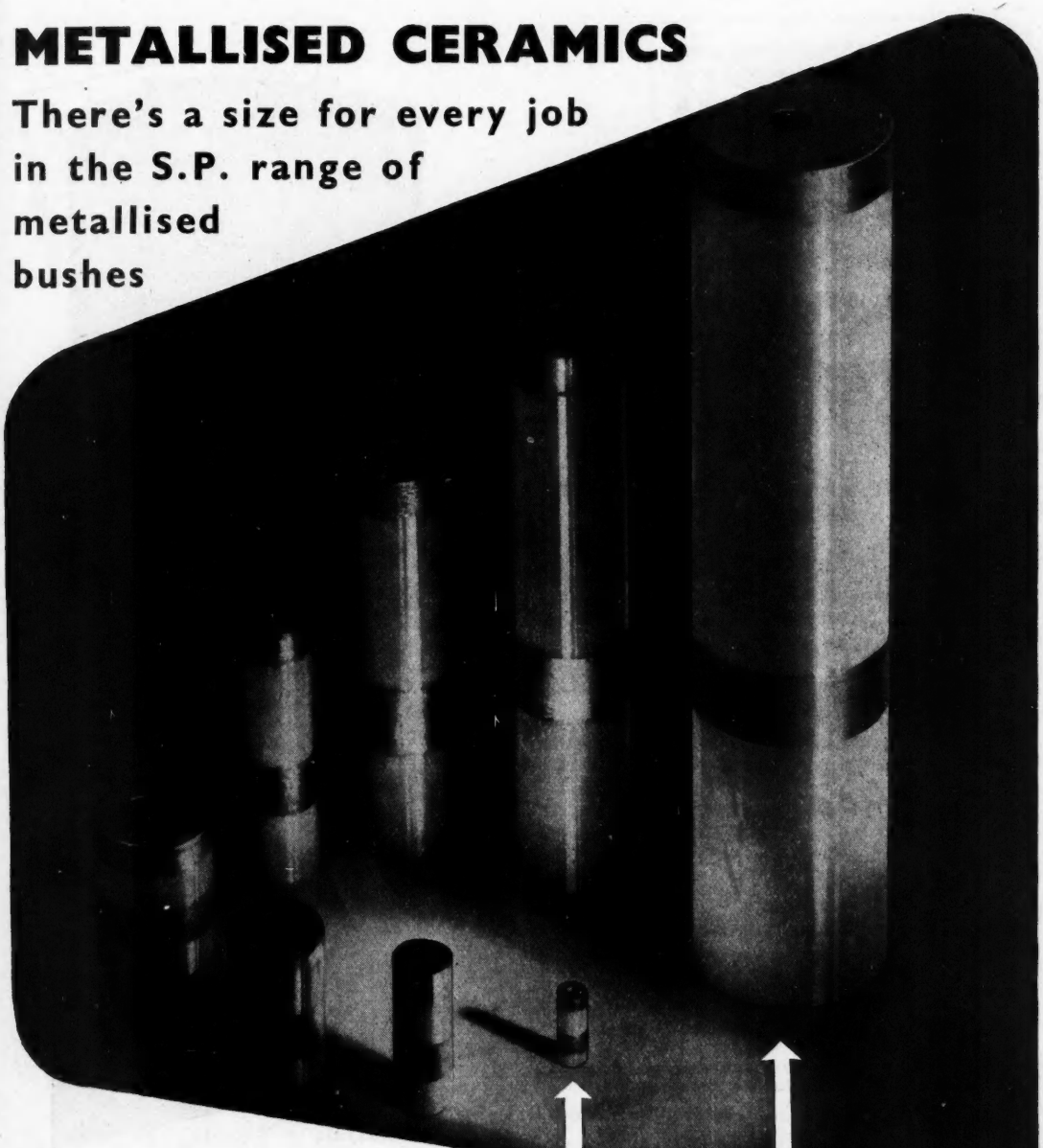

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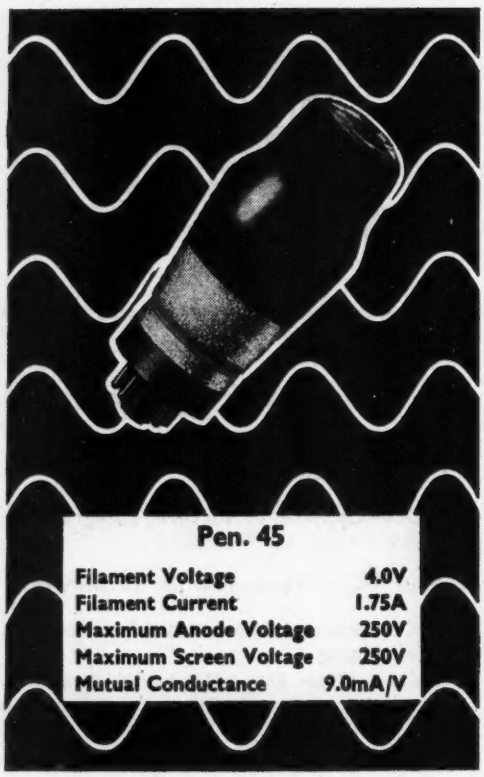

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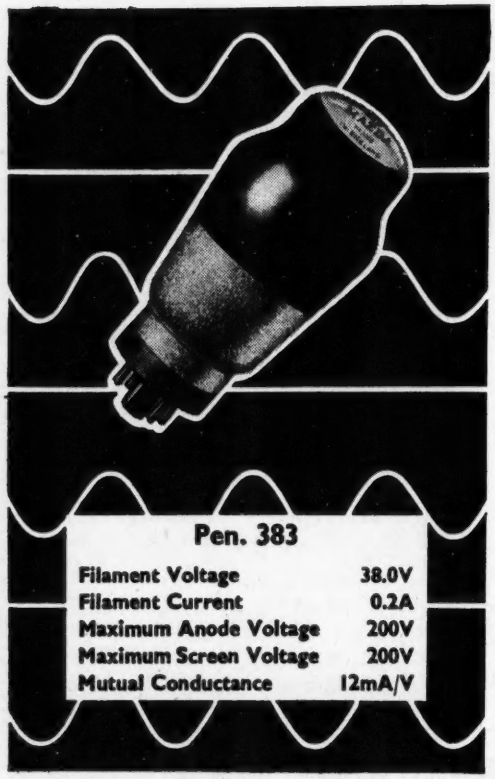

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# Patent Reform

THE subject of patents has been raised on more than one occasion in these notes, and no excuse is made for referring to it again, as it is one which is of interest to all engineers. The occasion is the publication of a book, " Inventions, Patents, and Monopoly," by P. Meinhardt*, which not only contains lucid and valuable information on all these, but also puts forward some suggestions for the improvement of the patent law which are worth careful consideration.

The main improvement which the author considers desirable is the division of patents into " licence patents " and " full patents " The first would be conferred on an invention showing a minor degree of ingenuity and would have a lower application fee and low renewal fee. The full patent would be reserved for an invention of sufficient importance to deserve a monopoly, and would be granted after an exhaustive search and examination. It is generally agreed that a number of patents granted today do not deserve the monopoly which the present law confers on them, but it is equally difficult to enforce a monopoly for a major or a minor patent.

Under the " licence patent " the small inventor would be able to enjoy a limited protection and would not be involved in expensive action to sustain it. Further, the author suggests that a " Small Inventors' Advisory Board " would be of use in advising the minor inventor and if necessary, enforcing his rights. This Board would undertake to look after the small inventor, even to the extent of financing deserving cases with a loan or guarantee.

One of the author's proposals for the Board is to provide an expert who will advise on the value and, presumably, the practicability of an invention submitted to them. One could hardly imagine a rush to fill such an appointment—the expert has yet to be found who can convince an inventor who argues with the conviction of ignorance of first principles !

The cost of patent litigation is the highest in this country, except U.S.A., and the author puts forward a liberal interpretation of claims as one of the factors which would reduce costs. He quotes the case of the " frosted lamps " patent as an example where an unwise drafting of the claim and a rigid interpretation by the Court invalidated the patent : " The patentee had opened his mouth too wide, and was punished by being deprived of protection for a valuable and useful invention."

Unfortunately, space does not permit of further quotation from Mr. Meinhardt's book, but anyone who reads it will echo the words on the jacket : : . . " a unique contribution to the literature relating to patents which may be read with advantage by all who desire knowledge and understanding of these matters."

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# High Fidelity Pictures

**The excellence of modern picture telegraphy can be judged from this composite block of which the left-hand side was made from the original photograph and the right-hand from the reproduced picture after transmission. At 150 lines per inch the structure is almost invisible, the only difference being in the background tone which is controllable.**—*See page 48.*

*Picture by courtesy of Muirhead & Co.*

# The Development of Photo-Telegraphy

By

W. C. LISTER, B.Sc., M.I.E.E.*

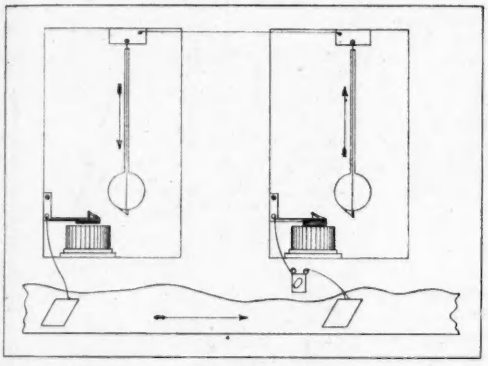


Fig. 1. Diagram of Bain's pendulum system, from the original patent of 1842.

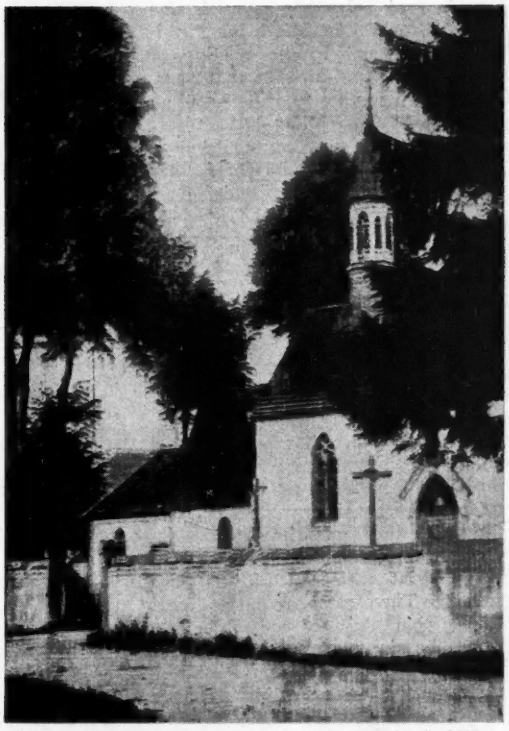


Fig. 2. Photograph transmitted by Belin's system in 1907.

IN considering the development of Picture Telegraphy, one is really considering a century of communication engineering. Even though one were blessed with omniscience and the gift of brevity, it would be presumptuous to attempt to survey such a field in a single paper. All that seems possible is to describe one or two pieces of apparatus of historical interest, and give some account of the component processes used in various combinations in the many workable systems which have been evolved.

### Early Historical Apparatus

The first system of electrical facsimile transmission was devised and demonstrated by Alexander Bain in 1842, a chastening thought for those working in the field over a century later on problems as yet unsolved. This system is worth considering here, not merely as an historical curiosity, but also because it fulfilled in an elementary way all the desiderata for facsimile transmission, at least of black and white subjects. Bain's system used printers metal type at the transmitting end for the subject. A pendulum carrying a light, resilient contact swung past the face of the type, the contact making a battery circuit to line as it touched the raised portions of the type face. For each beat of the pendulum the type was dropped down a step at a time. At the receiving end a similar pendulum and contact operated over a paper soaked in potassium iodide solution, the paper being traversed past the pendulum in the same manner as the type at the transmitter. An arrangement was provided whereby if one pendulum preceded the other slightly it was held back until the other reached the same position and both started together. Current from the transmitting contact passed via the receiving contact through the paper and produced a brown stain of iodine now familiar on many recorders using starch-iodide paper. The system, it will be seen, illustrates scanning in its most elementary form, synchronisation between transmitter and receiver by what until recent years was the best frequency standard obtainable, a pendulum clock, and a means of obtaining a visual record from an electrical current. Bain's transmitter apparently was little used, but his recorder, " Bain's Chemical Telegraph," was used for recording ordinary Morse code signals for many years.

The first successful facsimile system was probably that of Caselli who, in 1865, carried out tests between Paris and other French cities.

The introduction of photo-electric devices made possible the use of printed matter as the subject for transmission, and it became convenient to wrap the papers round drums which were rotated and traversed synchronously. One of the earliest pieces of apparatus operated photo-electrically was invented by

* Muirhead & Co. Ltd.

Dr. Shelford Bidwell in 1881. It was shown in operation before the Physical Society, and at the meeting of the British Association in that year. Although it seems to have been no more than a scientific curiosity, it does illustrate a period in the development of facsimile, and is of further interest in that it transmitted from a flat photographic plate and received on chemical paper wrapped round a cylinder. It is illustrated on page 39 and comprises a transmitting and a receiving instrument which are synchronised by the simple expedient of putting them side by side and joining their spindles together, although for clarity they have been illustrated separately. The transmitter consists of a wooden box carried by a nut on a screwed spindle having 64 threads per inch. As the spindle is rotated, the box is traversed horizontally. At the same time it receives a vertical motion from two cams mounted at each end of the same spindle. These cams are cut as linear spirals, but must, of course, have a return to the centre or fly-back, so that perfect scanning is only theoretically possible over the linear part of the cam. The material to be transmitted is in the form of a transparency, rather like a lantern slide, and is projected by means of a lens upon the white surface of the wooden box. In the middle of this surface is a small pin-hole and behind that, inside the box, a selenium cell. Thus, the mechanism is such that the pin-hole is caused to travel in a series of closely parallel lines over the projected image, and the light which passes through the pin-hole and consequently reaches the selenium cell varies as the illumination at the successive points of the projected image. The resistance of the selenium cell, of course, varies according to the light falling on it. The receiver consists of a platinum-covered brass cylinder which is rotated at the same rate as the transmitter cams and traversed by means of a similar screw to that on the transmitter. A platinum stylus bears on the surface of the cylinder, which is covered with paper soaked in a solution of potassium iodide. A potential is applied between the stylus and the cylinder, and a spiral brown line is traced on the paper. The intensity of this line varies with the current

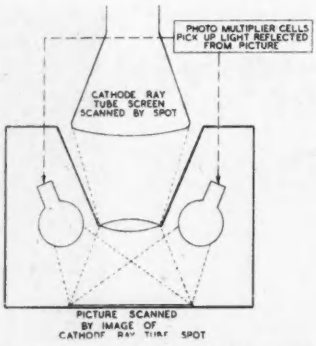


PHOTO MULTIPLIER CELLS PICK UP LIGHT REFLECTED FROM PICTURE
CATHODE RAY TUBE SCREEN SCANNED BY SPOT
PICTURE SCANNED BY IMAGE OF CATHODE RAY TUBE SPOT

**Fig. 3. Cathode Ray Tube Picture Transmitter.**

passing, which in turn is determined by the resistance of the selenium cell in the transmitter. A record of the illumination falling on the projected image is thus obtained at the receiving end.

### Twentieth Century Systems

In 1897 Belin started work on the problems of picture transmission, and in 1907 constructed his first complete equipment on which the picture in Fig. 2 was received. The development of the thermionic valve, as with most communication systems, marked a turning point, and from the early 1920's onwards picture systems became a reality. Usable quality received pictures were obtainable on a number of systems, among which may be mentioned Bart-Lane, Korn, Belin, Jenkins, the Ferré, the A.T. & T., R.C.A. and Siemens. Some have fallen into disuse, but others, such as the Muirhead-Jarvis and Post Office-Cable & Wireless equipments in this country and the Times Telephoto, Finch and Hogan equipments in America, have sprung up in their place. Rather than consider individual systems, it seems best to consider the component processes.

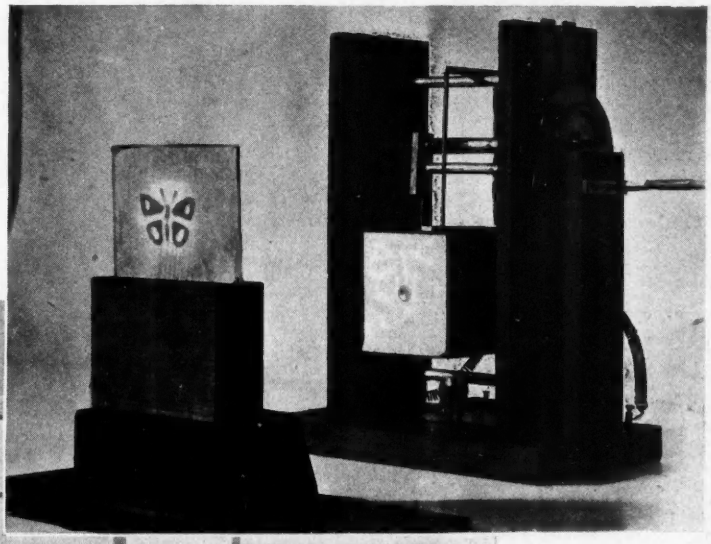
### Transmitting Processes

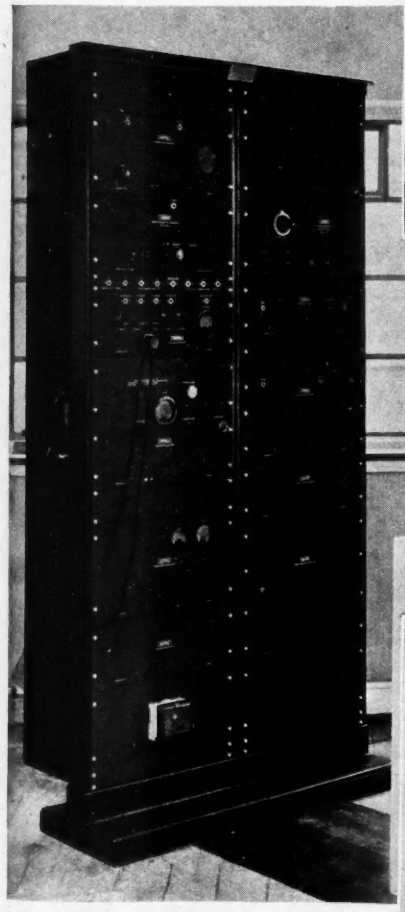
With one or two exceptions, and the systems of Bain and Shelford-Bidwell are among them, the scanning arrangement for the transmitter has always comprised a rotating drum traversed along by means of a screw. In some cases simple gearing between the drum and the screw thread, as on a screw-cutting lathe, has been used; others have used differential screws, and the Muirhead-Jarvis system uses a ratchet indexing device. In one or two systems, notably the R.C.A. illustrated in the description of the Cable & Wireless equipment on page 50, instead of the drum being traversed longitudinally, the optical system is similarly traversed.

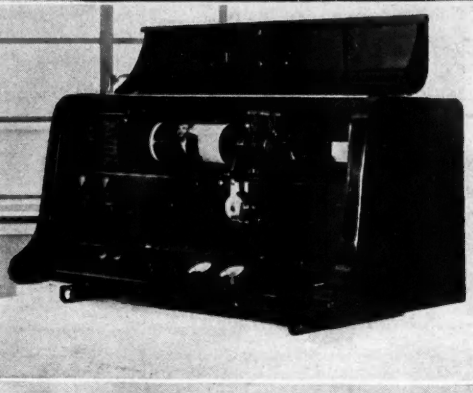
The methods of changing variations in picture density into corresponding electrical variations fall into two classes — electro-mechanical and electro-optical. The Bain's system, in which contact is made with metallic raised surfaces, is in the first class, but, of course, only gave pure black and white and no gradations in tone. In the Belin system, which found considerable use, the photograph for transmission was reproduced in relief on a special gelatine and then scanned with a stylus controlling a rheostat. This was replaced by a microphone in 1909. The electro-optical systems originally used selenium cells, but now, of course, use modern photo-cells. In all these a brightly illuminated portion of the picture is focused on to the photo-sensitive device, usually with a microscope objective, and variations in intensity of the picture give corresponding variations in photo-cell current. The selection of the particular portion of the picture may be either by means of an aperture in the condenser system, or, alternatively, the picture is floodlit and the required portion of the picture is selected with an aperture between the objective and the photo-cell. This is more generally used nowadays, since any wrinkling of the picture on the drum does not shift the position of the transmitted image.

A third electro- optical system which is of particular interest uses television practice (Fig. 3). The picture is placed on a plane surface, and an image of the whole screen of the cathode-ray tube is focused on to it by means of a lens. The spot on the cathode-ray tube is scanned over the whole surface of the tube screen by the normal television process, and consequently its image similarly scans the picture. Reflected light from the picture is picked up by means of two electron multiplier photo-cells placed on either side of the lens. This system was used during the war by the Germans for

# Picture Systems Ancient and Modern





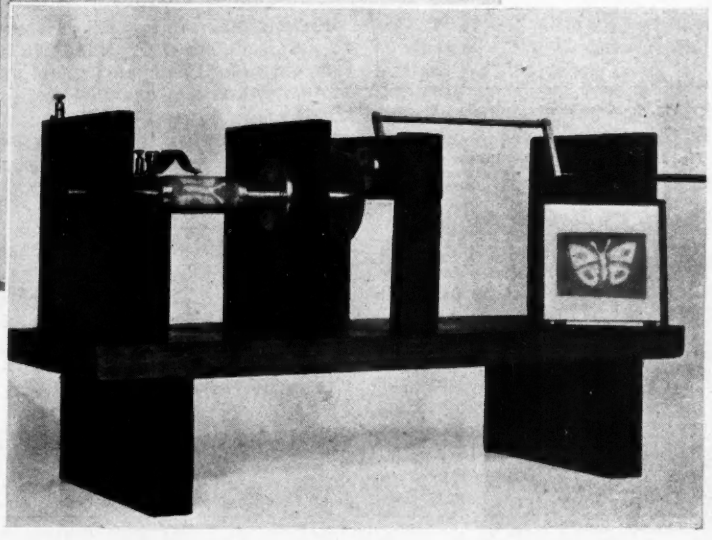


**Shelford-Bidwell's Apparatus of 1881.**

**Above: Transmitter showing transparency, photo-cell box and cam for vertical scanning.**

**Below: Receiver, showing picture on drum and another picture mounted alongside.**

*—By courtesy of the Science Museum.*



**Muirhead-Jarvis Transmitter, 1946, with transmitter cabinet (above, right) with picture on drum, and double transmitter rack giving telephone facilities in addition to picture signal control.**

the transmission of maps in the field. It is not suitable for use over lines because of the wide frequency band required, but over radio links it can, of course, be made extremely fast.

The electrical variations corresponding to picture tones are in general in the form of a fluctuating direct current. These are obviously difficult to amplify or to transmit over a normal communication link The commonest arrangement with the optical systems is to interpose somewhere in the light path a chopper disk which interrupts the light on the photo-cell at a constant frequency, and provides a photo-cell output which can be amplified and filtered. For normal line working where a band width of the order of 2,500 cycles per second is available, a modulation band of about ± 1,000 c/s. is used. At first sight one would choose a chopper disc frequency of about 1,250 c/s., but for reasons which cannot be entered into here this cannot be modulated by a 1,000 c/s picture signal. A higher frequency is therefore chosen, and in a typical case the chopper disc provides a frequency of 7,200 c/s. modulated by the photo-cell ± 1,000 c/s. This is heterodyned by an oscillator of 5,900 c/s to give a carrier of 1,300 c/s. modulated ± 1,000 c/s. Relatively slow transmissions over telegraph links have, however, been carried out by a code system in which picture intensity is translated into code signals on a punched tape. In the case of radio transmissions, where simple amplitude modulation is impracticable owing to fading, the earliest satisfactory systems split the picture up into small areas, rather like a half-tone picture, and transmitted dashes of varying length corresponding to the intensity of each picture element. The amplitude of these dashes was relatively unimportant. The introduction of frequency modulation rendered this system largely obsolete, and most radio links now use sub-carrier frequency modulation, so that the actual transmitted signal can go out over a normal amplitude - modulated transmitter. The Cable & Wireless equipment is designed on this basis.

### The Communication Link

It will thus be seen that the actual communication link can be a line or radio, and it will be obvious that the limiting factor on speed of transmission for a given picture definition is the frequency band available in this link. In order to fix ideas it might be as well to give here some figures on the speed of operation over normal Post Office circuits. A picture 10 in. by 8 in. may be scanned at 150 lines to the inch at two revolutions per second, and the quality of the received picture, using a band width of ± 1,000 c/s., will be such that it is difficult to distinguish it from the original picture. The time of such a transmission would be ten minutes. Improvement in picture detail can, of course, be obtained by increasing the number of lines per inch. In order to keep the definition in the direction along the scanning lines as high as

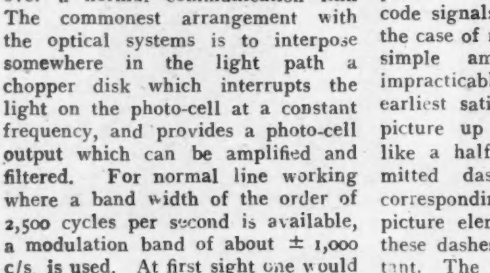



**Fig. 4. Continuous Recorder, Electrolytic Paper.**

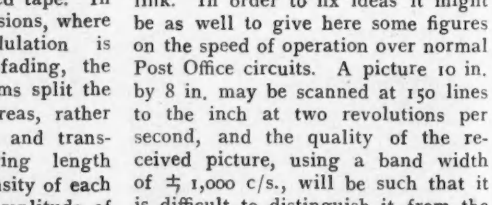



**Fig. 5. Continuous Recorder, Carbon Paper.**

**Fig. 6. Muirhead Phonic Motor with 51 teeth on the rotor and corresponding teeth on the stator poles.**

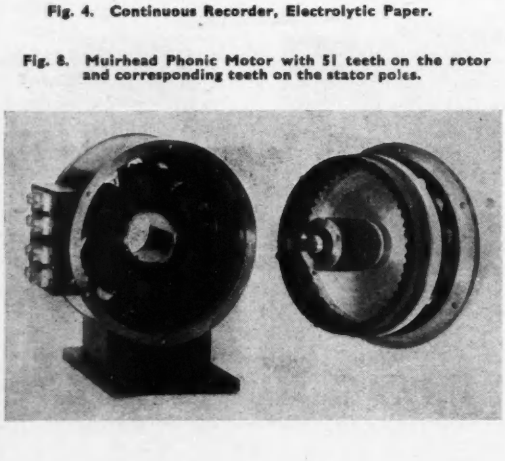
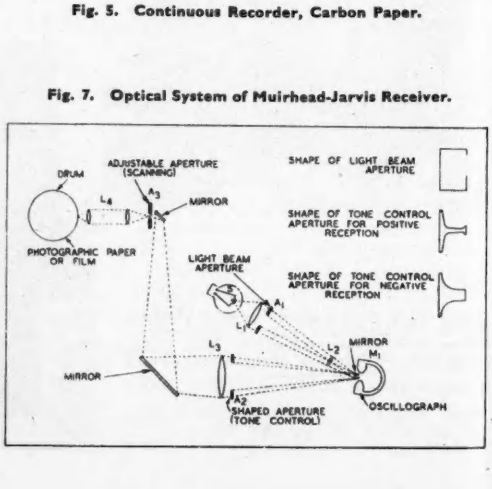


**Fig. 7. Optical System of Muirhead-Jarvis Receiver.**



that provided by increasing the number of lines, either one must reduce the speed of rotation or increase the frequency band.

**Receiving Processes**

At the receiving end the most important factor, apart from the scanning system which is in general identical with the transmitter, is the means adopted for changing current variations into variations in intensity of the received picture. The electrolytic system, which was used by Bain over 100 years ago, is still in use, although the chemical composition of the solution has changed. A sample of modern facsimile received on electrolytic paper is illustrated elsewhere in the Home Newspaper shown on p. 43. The R.C.A. tried various forms of recorder apart from photographic processes, which are mentioned separately. One form used a continuous spray of atomised ink projected on to the receiving paper and regulated by a deflecting vane operated by a balanced armature magnetic driver. Carbon paper recorders were also used, the early types consisting of a stylus dragging over the carbon and white papers. Another type which was used for recording on a continuous reel of paper utilised a chopper bar operated by the signal and a scanning helix on a cylinder against which the paper was pressed by the chopper bar. One complete rotation of the scanning helix corresponds to one rotation of the transmitting drum, and the scanning lines run across the paper parallel to the axis of the helix. The principle of this can be seen by reference to the two diagrams, Figs. 4 and 5, and is that used in most of the continuous paper systems, no matter what the actual recording medium may be. Where it is used for electrolytic recording, the chopper is replaced by a fixed bar and the signal applied between this and the helix. Heat sensitive papers have also been used. These are of two types: chemically treated papers usually with a coating of some nickel salt, and waxed papers. A jet of air heated to a fairly high temperature is directed upon the surface of the paper, and in the case of the chemical paper the salts on the surface decompose leaving a black residue. In the case of the waxed papers, where the wax is melted it is absorbed by the paper and subsequently water ink is run over the surface. The difference in the inking between the areas of crystalline and melted wax provides the difference in intensity of the picture. The type of paper which has more recently come into use for recording purposes is Teledeltos paper. This paper is coated on one side first with a layer of carbon and then with finely divided metal rather like Mansbridge condenser paper. The metallised surface is in contact with the metal surface of the recording drum, and a metal stylus presses on to the other surface. When a potential of 100-200 volts A.C. or D.C. is applied between the stylus and the metal drum, burning of the paper takes place and produces a black mark. The intensity of the burn depends on the potential applied, and this is determined by the signal voltage; gradations of tone are thereby obtained. Fig. 6 shows a picture received on Teledeltos paper on a Times Telephoto machine.

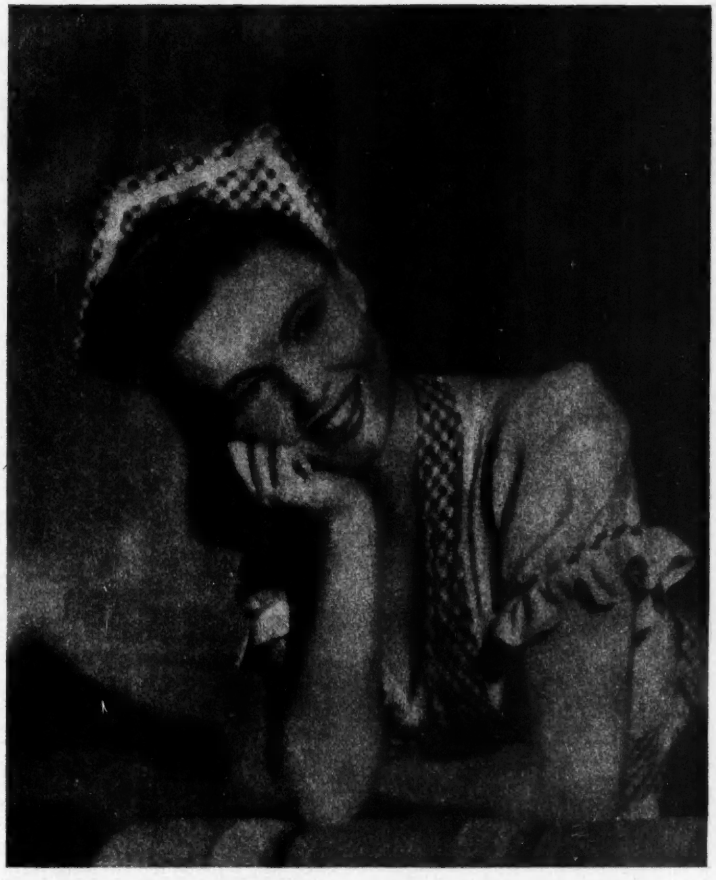


**Fig. 6. Picture on Teledeltos Paper received on Times-Telephoto machine.**

The receiving processes so far described have been non-photographic, and in general do not give very good reproductions of tone values in a picture. For really first-class reproduction of the quality which the newspapers have required and obtained for many years, it is necessary to use photographic technique. In transposing variations in the received signal into variations in light intensity, which can be recorded photographically, a number of systems have been developed. The most common makes use of an oscillograph which is fed from the rectified received current. Light reflected from the oscillograph mirror sweeps

across a fixed aperture so that more or less light passes through the aperture depending on the strength of the signal. The light that passes the aperture is then focused on to the paper or film on the recording drum. This optical system is worth a little attention, since it has been used on many different receivers and continues to be used on most of the European facsimile systems to-day. Referring to Fig. 7, light from a source S is condensed by the lens $L_1$ on to the mirror $M_1$ of a Duddell oscillograph loop which carries the signal current. An image of a rectangular aperture $A_2$ is formed by the lens $L_2$ in the plane of a second aperture $A_3$. The lens $L_3$ is arranged to form an image of the oscillograph mirror $M_1$ on the final aperture $A_3$. $L_4$ is a high-power objective arranged to form an image of $A_3$ on the drum. It will be seen that as the image of the light beam aperture $A_1$ is swung across the shaped aperture $A_2$ the intensity of illumination at the scanning aperture will change and so will the intensity of the light spot on the drum. $A_2$ is shaped to provide compensation for non-linearity in the photographic film or paper. $A_3$ is adjustable so that the width of the light spot on the drum may be made exactly equal to the width of the scanning pitch.

Another system which is extremely simple optically makes use of what are variously known as Glow Tubes, Crater Tubes or Hot Dogs. A glow tube of neon, argon, helium or a mixture of gases, is formed so that the glow takes place in a crater which provides a point source of fair intrinsic brilliance. The signal is impressed on the tube and the light intensity is approximately linear with applied voltage. A single objective serves to focus the light on to the recording drum. The system suffers from two disadvantages: it is not possible to provide tone control except by making the amplifier non-linear and the extent to which this can be done is limited. Secondly, it is difficult to get good positive reception on paper due to the value of the extinguishing current.

The third system which was used in the early Siemens equipments made use of polarised light and a Kerr cell to change the light intensity. Two Nicol prisms polarised in the same plane pass light from the light source to the final aperture. Between these Nicols the Kerr cell is interposed. Applying a signal to the plates of the cell alters the plane of polarisation and alters the amount of light leaving the system. This system again suffers from the disadvantage that "tone control of the picture can only be obtained by equalisation in the amplifier."

The last receiving system which will be dealt with here is that used with the C.R. tube transmitter described earlier. In this the received picture is formed on the screen of the tube as for a television picture, and is simply photographed with an ordinary camera.

### Synchronisation

The question of synchronisation between the scanning systems at the transmitting and receiving ends has been tackled in a number of ways. The usual arrangement is to provide some sort of frequency standard at both ends and use these to control the driving motors. Clocks have been used in this way, but most systems have used tuning forks, although the Cable & Wireless equipment designed by the Post Office makes use of crystals. Tuning forks were first used for synchronisation by D'Arlincourt as early as 1869, and they still provide the simplest form of standard frequency source for this purpose. Many methods for controlling motor speeds from tuning forks have been devised, the most direct being the phonic motor invented independently by Rayleigh and La Cour in 1878 for frequency determination of tuning forks. Both the Cable & Wireless system and the Muirhead-Jarvis system make use of the same type of phonic motor, the construction of which can be seen from the photograph Fig. 8. The stator of this machine is fed with alternating current and the winding polarised with D.C. Under these conditions, if the rotor is spun up to a speed such that it moves forward one tooth for each cycle, it will fall into step and run synchronously. The motor shown has 51 teeth and will run at 20 revolutions per second when fed with 1,020 c/s., the synchronising frequency established by the C.C.I.T.

Another method of synchronising a machine consists in providing a D.C. motor driving an alternator which, at synchronous speed, generates the same frequency as the controlling frequency standard. The output of this machine is fed to the anode of a valve, and the control frequency is applied to the grid. If the two frequencies are in synchronism, the valve will present a constant load to the alternator. Any change in mechanical load on the motor will change the phase of the alternator output, and consequently the phase relation between the grid control voltage and the anode voltage from the alternator. This will alter the load on the alternator in such a direction as to tend to maintain synchronism.

Control methods of the type described above are used whether the frequency standard is a tuning fork or a crystal, and even in cases where the synchronising frequency is transmitted over the communication link. In the case of crystals, a divider has to be introduced to bring the frequency to a suitable value for operating the control. The frequencies used for this purpose in recent years have been between 500 and 2,000 c/s. In some of the earlier aparatus frequencies of the order of 50 c/s. were used from contact-driven tuning forks operating phonic motors of the type common in synchronous telegraph working.

### Conclusion

The manner in which the various component processes which have been described have been assembled together and utilised in working systems of picture telegraphy, is not so much beyond the scope of this article as beyond the space available. However, elsewhere in this issue will be found descriptions of several modern systems to which the foregoing may serve as an introduction.

The author would like to express his thanks to Messrs. Muirhead & Co., Ltd., for permission to publish what is in effect a background of knowledge acquired in their laboratory, to Messrs. Belin for the picture in Fig. 2 and for information on their early system, and to "R.C.A. Institutes and Technical Press" from whose book, "Radio Facsimile," Figs. 1, 4 and 5 were taken.

# A Four Page Newspaper in 15 Minutes — *The Hogan Facsimile System*

FAX-NEWS

October 21, 1946

## New NPFS Service Broadcasters' Aid

A complete facsimile program and development service, designed to assist broadcasters and newspaper publishers in the operation of Facsimile newspapers, has been developed by Radio Inventions, Inc.

This service, known as Newspaper Publishers' Facsimile Service, is supplying its subscribers with packaged reports of experimentation in Facsimile newspaper development.

A staff of NPFS experts is determining the best available typefaces for facsimile reproduction, the most effective layouts, the uses of various types of art for illustration, and the fastest and most efficient methods of making pages for reproduction both with and WITHOUT the use of conventional type-setting methods.

In addition, NPFS will devote considerable time and engineering research to further development of Facsimile in the interest of broadcasters and newspaper publishers, and will offer actual programs for rebroadcast as soon as Facsimile newspapers are on the air.

### 1948???

Jack Benny is guest tonight on Bob Hope's program (WJZ-10 pm). Tune in at some time for photograph of Benny.

# FAXIMILE READY TO CARRY PRINTED NEWS INTO HOMES

HOW far the Facsimile Newspaper broadcast from a central radio station and reproduced in the reader's home, will become a serious competition of the ordinary newspaper is a matter for speculation.

That it is perfectly practicable has been demonstrated in America by several manufacturers of facsimile equipment. The reproduced page of Fax-News in which this is inset was received on a home recorder which will reproduce four such pages in fifteen minutes.

The transmitter uses a conventional optical system scanning a rotating drum which may be seen in the illustration. The signal is sent out from a standard F.M. broadcast transmitter, the recorder is fitted with a 400 ft. roll of electrolytic paper, 9½ in. wide, and records at the rate of just under 3½ in. per minute. The marking device is the printer blade which makes electrical contact across the whole width of the paper. A wire helix mounted on a drum directly underneath the printer blade makes contact with the underside of the paper. (Refer to Fig. 5, page 40).

As an aid to broadcasters, Facsimile soon will be flashing printed words and pictures from radio stations into radio listeners' homes.

Research by Radio Inventions, Inc. has created Faximile broadcasting equipment which prints four pages 9½ by 12 inches in 15 minutes by Hogan Faximile instantly and directly without photographic or finishing processes.

The 9½ by 12 inch format lends itself perfectly to newspage layouts with standard-size newspaper columns.

Through Faximile, current radio news broadcast coverage can be expanded to include printing of radio-reproduced newspapers within the home — newspapers complete with baseball and football box scores, stock market tables, weather maps, crop reports, race results, election returns, action news pictures, fashions, detailed radio programs, comics and other written and pictorial news matter.

Vocally broadcast flash and bulletin matter can be supplemented by illustrations, diagrams and expanded text reproduced by Faximile at a speed faster than the radio news announcer can speak.

Faximile newspages, like the pages of newspapers, can carry advertising copy.

**HOGAN FAXIMILE** — Inventor John V. L. Hogan, president of Radio Inventions, Inc., is shown watching Faximile studio console in operation. Reproduction of Screen Star Ray Milland on the "recorder" has just been sent from photo Faximile "scanner" on right.

# Commercial Applications for Picture Telegraphy

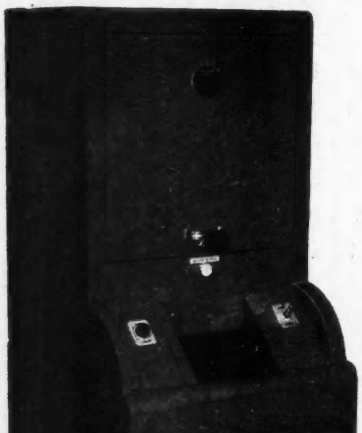
By R. C. WALKER, B.Sc., A.M.I.E.E., A.M.I.Mech.E.

RADIO experimenters of the "twenties" will recall the early apparatus employed for still picture telegraphy, notably that simple apparatus the Fultograph[1] which came within the scope of the home experimenter. Though the crude results of the Fulton system are now little more than past history, and were soon eclipsed by other systems for news picture transmission, the process had the merit of extreme simplicity to a degree that forced many people to express the opinion that for industrial processes not requiring the gradations of half-tone illustrations, it would be resurrected at some later date.

These prophetic views now seem to be fulfilled by the rapidly extending use, during the past few years, of facsimile equipment in America, under the auspices of the Western Union Telegraph Company.[2] This is an application for amplifier equipment, thermionic valves, and photo-electric cells which may well extend to this country and find general adoption. Much of the extension of the use of facsimile transmission has been the development of a suitable dry recording paper known as "Teledeltos," a medium which is impervious to light or moisture, but is affected by electrical impulses which produce a black record. The paper is extremely fast in action, requires no processing either before or after recording and produces a clean and permanent impression at a fraction of the cost of photographic film or paper. The amplifier facsimile tone signals are applied to the paper through a stylus which rides continuously on the paper surface.

The process is being employed: (a) For regular telegraph business chargeable at telegraph rates, the addressee receiving a teleprinter or facsimile process telegram. (b) General transmission of drawings, tabulations or blue prints from one place to another under special rates with delivery of facsimile copies.

In the first application, a simple system has been devised for collecting telegrams and transmitting them to a central office in the sender's city for re-transmission to the addressee in the city of destination.



**Western Union Automatic Telegraph Facsimile Recorder. Type 801.**

The transmitter for this purpose resembles an ordinary letter box. The customer merely presses a button on the cabinet and inserts the telegram into a slot in front of the machine. Both wall mounting and table models of the transmitter are employed in this service. The transmitters occupy as small a space as an automatic vending machine and are installed in office buildings, hotels, railway stations and other public places. Where a transmitter is installed for unattended service in an office building, subscribers to the service are supplied with keys. Alternatively, in public places, coin feed mechanisms are incorporated in the machine. Blank forms are provided so that a standard size of image is provided for transmission.

Having written or typed the message on the prescribed form, the user presses the starting button which operation sends a signal to the central office where the call is registered by a line amplifier. The same operation applies a battery to one line wire which opens the transmitter chute and illuminates a panel indicating to the user that the telegram should be inserted.

As soon as the message is inserted, the chute closes to prevent a second message being dropped in and the message form is automatically wrapped round the cylinder and scanned by the photo-cell in the usual way.

On receiving the call, the operator at the central office plugs in a recorder to the line, records the message and sends a call back signal which removes the message form from the transmitter drum. At the same time, the sender is advised by an illuminated panel which reads "telegram accepted," that the transmission is complete and the machine ready to receive the next message.

All the usual appliances and circuit accessories common to telephone circuits can be applied to this equipment. A number of transmitters can be operated from one line pair with relay interlocking connexions to prevent cross talk, panel indication of the line engaged condition, etc. Moreover, call back signals from the receiver to the transmitter provide a complete test of the sending instrument before it is possible for a telegram to be inserted in the transmitter.

More recently, facsimile processes have been brought into transport systems in America as a means of providing new communication facilities by delivering train orders to locomotive crews.[3]

Where the distance between stations is considerable or where stations are closed at night, this provides a means of communication which avoids errors, since once prepared for transmission, an order is never again manually copied. Duplication is easily provided and messages can be transmitted so as to be ready awaiting the arrival of the train since the receiver is provided with receptacle into which the sheets with the mes-

sages on them fall, whether there is anyone waiting to receive them or not. The type 703 transmitter which is used for this purpose, utilises the standard scanning of 180 r.p.m. with a carrier frequency of 2,500 cycles, though provision for a carrier frequency of 3,000 and a drum speed of 360 r.p.m. can be provided when required.

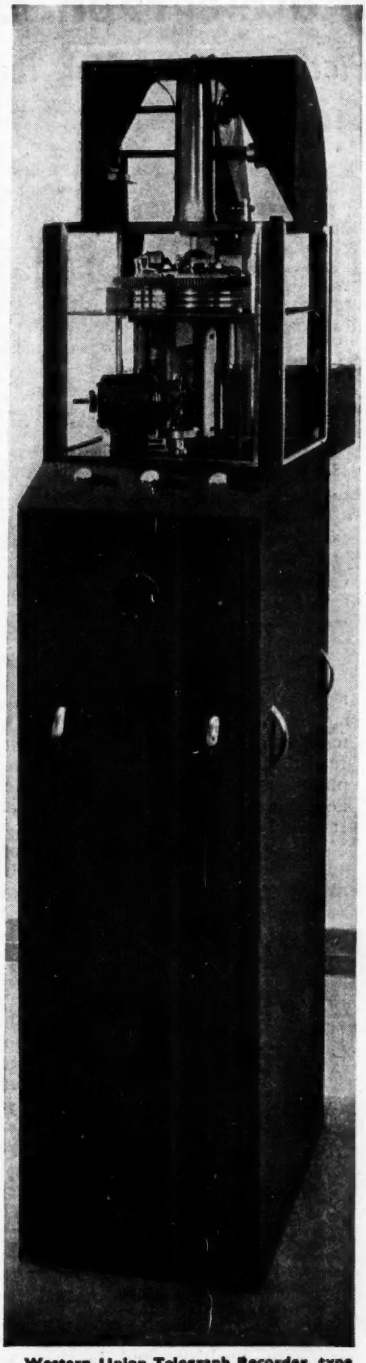
The line circuit carries the facsimile tone signals and the D.C. control signals and operates with an earth return. The recorder can be controlled by the transmitter through a three-position polarised relay in one line wire and a similar relay in the other line enables certain operations of the transmitter to be controlled by the recorder. Normally, these relays occupy the centre position with open circuit contacts on either side. The tone signals are separated from the D.C. control pulses by condenser filters.

As with the previously described equipment, manual push-button control at the transmitter connects power to the recorder through the line relay. A second line relay at the transmitter is then operated when the recorder is ready to start and illuminates a panel on the transmitter reading "Deposit telegram." In two seconds, therefore, both instruments are tested and the possibility of failure or lost messages is eliminated.

The Teledeltos sheets in the form of interleaved blanks are stacked so as to feed individually to a pair of light springs. In reaching its proper position, the blank interrupts a light beam which actuates a relay to arrest the feed and hold the blank in the phase position, at the same time completing the circuit which illuminates the panel on the transmitter.

At the top of the transmitter blank is an opaque black square which is scanned during the first revolutions of the drum and the interruption of the tone signal which this causes, locks the recorder relay and ensures that the recorder blank starts in step with the transmitter. Immediately recording starts, another blank is drawn forward ready to be fed to the drum for the next message.

After the message is completely scanned, a contact on the transmitter removes the D.C. potential from the line and releases the recording relay. This energises a magnet operating a spatula which automatically strips the record from its drum and deposits it into a bin at the foot of the instrument. As the recorded message leaves the drum, it reverses the D.C. line polarity which actuates a similar device which removes the message from the transmitter drum.



**Western Union Telegraph Recorder, type 41, which transcribes and ejects telegrams automatically. The paper moves vertically along the central cylinder.**

To enable one operator to send train orders to several recorders located at different points on the system over a single line pair, the transmitting station selects the receivers by a telephone dial which in turn controls a selector switch according to established practice in telephone circuits. A call-back through a motor-driven code wheel advises the operator both that the correct station has been selected and that its blank is phased ready to record. Acknowledgement of receipt can be given by the train conductor when the message is picked up. By pressing a button at the side of the receiver, the call-back code is altered by the insertion of a long dash signal. When the operator next dials this station, he will know from the altered code that the message has been picked up.

#### Duplicators

This process of facsimile recording is also applicable to cases where a number of copies of the received matter are required. For this purpose, a mimeograph stencil or hectograph carbon is placed over a sheet of white paper on the recording drum. An electromagnetic percussion unit here takes the place of the stylus and is propelled by the impulses received from the transmitter and reproduces the original as a stencil or hectograph master copy which is subsequently used on an ordinary office duplicating machine.

For business use, a transmitter and percussion-type recorder are mounted on one carriage with a double-length drum.

The material to be duplicated is wrapped round the drum at one end, while the stencil or hectograph carbon is wrapped round the other end. The optical system and photo-cell then scan the original on one half of the drum, while the percussion unit reproduces the copy as a stencil on the other half. This machine can be made to operate with a minimum of controls and is useable by the general office staff with no particular training. It enables copies of blue prints and line drawings of any kind to be rapidly produced.

[1] Haynes, F. W., "The Fultograph," *Wireless World*, Oct. 24th, 1928.
[2] Hackenberg, J. H., "Facsimile Telegraphy—Some New Commercial Applications," *Electrical Communication*, Vol. 18, No. 3, Jan., 1940, pp. 240-251.
[3] Hackenberg, J. H., and Ridings, G. H., "Train Orders by Facsimile Telegraphy," *Electrical Communication*, Vol. 21, No. 2, 1943.

# New Phototelegraph Equipment

## *I—A Picture System for the Press*

FOR many years the newspapers in this country have operated their own picture telegraph circuits, mainly with French or German terminal equipment. Those of the National Dailies which print simultaneously in different population centres, such as London, Manchester and Glasgow, commonly send by picture telegraph from their main office not only all their pictures, but sketches of the make-up of the different editions. Muirhead & Co., Ltd., in collaboration with F. W. Jarvis, Communications Manager of the *Daily Mail*, have now produced picture telegraph equipment expressly for the newspaper traffic, and prototypes were demonstrated at an exhibition held in London in June of last year. The Muirhead-Jarvis transmitter is illustrated on page 39. The receiver is very similar in construction and is arranged for operation in full daylight, a dark room being necessary only for loading the drum camera and developing the received picture. The equipment, which is completely A.C. mains operated, is arranged for amplitude modulation. For use in radio links, however, a sub-carrier frequency modulation unit may be provided.

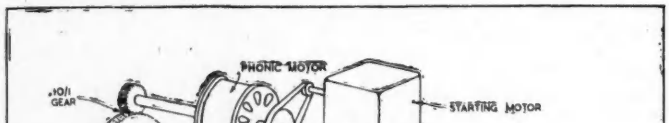



**Fig. 1. Schematic arrangement of transmitter showing drive and feed mechanism.**

### Mechanical Details

Perhaps the most important factor in a really first-class picture telegraph system is the standard of mechanical design and workmanship which goes into the scanning and optical systems. In this equipment the transmitter and receiver are very similar mechanically. The main operating unit in each case is arranged for mounting on a table or bench, and the electronic equipment is rack mounted. In both transmitter and receiver the picture drum and the phonic motor which drives it are mounted together with a lead screw of ½ in. pitch on the carriage, which runs on a slide formed on the main bed of the machine. The lead screw runs in a nut which is fixed to this bed. Thus, if the lead screw is turned, the carriage moves forward. The drum spindle carries an eccentric which works a rocker arm bearing a pawl. This pawl engages with a 150-tooth gear wheel attached to the lead screw, and for each revolution of the drum spindle feeds it round by a certain number of teeth and thus moves the carriage. The number of teeth which the pawl is allowed to feed on is determined by a sector plate over which it runs and which keeps it clear of the ratchet wheel. It is only when it runs over the edge of the sector plate that the pawl can engage with the ratchet wheel. By altering the position of this sector plate, the pawl can be made to feed 0, 2 or 3 teeth per revolution of the drum. 0 corresponds to neutral, 2 gives 150 lines of the scanning per inch, and 3 gives 100 lines per inch.

Actually, as will be seen from Fig. 1, two pawls back to back are provided and two separate sector plates. When one pawl is in operation, the other is lifted clear by its sector plate. When this second one is brought into operation and the first one lifted, the ratchet wheel is indexed round in the opposite direction and the direction of traverse of the carriage is reversed. The two directions of traverse, one for transmission and the other for reception, are necessary to obtain the reversal of image required on the negative. The machine is also capable of receiving positive, and in this case the direction of traverse is the same for both transmitter and receiver.

Both the bed of the machine and the carriage are of cast iron, and the slide consists of the conventional machine-tool Vee and flat which are machined, ground and hand scraped. On the carriage three steel pads are provided to form the contact points with the slide, two on the Vee and one on the flat surface of the slide. The drum spindle is driven from the phonic motor through a 10:1 gear, the meshing of which can be controlled by an eccentric trunnion mounting for the motor. Flutter in the system due to very slight imperfections in the gearing is almost entirely removed by the provision of friction pads. The drum is mounted between centres and is driven by a dog. At the tailstock end a running centre is provided which is withdrawn by a lever for removal of the drum.

Two drum speeds are provided, one of 1 r.p.s. and the other of 2 r.p.s., the change-over from one to the other being effected by using 1,020 c/s. direct from the synchronising tuning fork for the 2 r.p.s., and half this figure from a divider for the 1 r.p.s. speed. Scanning rates of 100 lines per inch and 150 lines per inch are available, and this change is effected by a control on the traverse pawl

mechanism and a second control which alters the final aperture.

The whole mechanical and optical unit enclosed within the casing of the instrument is mounted on anti-vibration mountings so that it is mechanically insulated from shocks due to closing the cover and to building vibrations.

### Electrical Arrangement

A block schematic of the transmitter is given in Fig. 3. Light reflected from the picture on the drum reaches the photo-cell via a chopper disc which interrupts it 7,200 times a second. The output from the photo-cell after amplification is passed through a high pass filter, with a cut-off at 5,000 c/s., where the actual picture frequencies of 0-1,000 c/s. are removed, and a carrier of 7,200 c/s. modulated with the picture signal of 0-1,000 c/s. is left. After further amplification this modulated signal is fed to an ECH.35 frequency changer with an oscillator of 5,900 c/s. This delivers a carrier of 1,300 c/s. modulated with the picture signal. The low pass filter removes the 5,900 c/s. and 7,200 c/s. frequencies, together with any unwanted modulation products. After further amplification a signal of up to 2½ volts into 600 ohms is available to feed into the line.

The receiver block schematic is shown in Fig. 4. The signal comes in as a carrier of 1,300 c/s. modulated with the picture signal, and after initial amplification it is fed into a non-linear amplifier which provides some measure of compensation for the non-linear photographic characteristic of the film or paper.

From this point the signal passes through an amplifier and demodulator to a low pass filter which removes the 1,300 c/s. The output from this filter is the actual picture signal of 0-1,000 c/s. This is fed into the Duddell oscillograph unit, and the mirror on the oscillograph deflects a beam of light across an aperture and thus regulates the amount of light reaching the photographic material on the receiving drum.

### Synchronisation

Synchronisation between the transmitter and the receiver is obtained by providing a tuning fork at each end controlling the phonic motor driving the scanning system. The frequency of the tuning fork may be adjusted over a range of ± 200 parts in $10^6$ by rotating a magnet in the region of the tuning fork driving coils. This alters the polarising field in the air gap of the driving coil magnetic circuit, and gives rise to a change in frequency. A change in amplitude also takes place which is corrected by means of a potentiometer ganged on the same spindle as the magnet. This arrangement may be seen by reference to Fig. 5. The transmitting and receiving forks are synchronised by observing a horse-shoe type of figure on the cathode-ray tube at the receiving end and adjusting the receiving fork accordingly. The transmitting fork tone is, of course, sent down the line for this initial adjustment. The receiving fork tone is fed on to one pair of plates of the tube and on to the other pair through a phase splitting condenser; this produces the normal circular trace. The transmitting fork tone is then applied to the grid of the tube, and deflects the beam for a part of the cycle to an extent which suppresses it entirely. This gives a figure on the tube which is shaped like a horse-shoe and which, if the forks are exactly the same frequency, is stationary. Any difference in frequency results in rotation of the figure which changes direction when the two frequencies pass through the zero beat position.

### Phasing

It is not, of course, sufficient simply to have the transmitting and receiving drums rotating and traversing synchronously; they have to bear the correct phase relationship to each other, and to ensure this a phasing signal is sent down the line after the transmitting drum has been set in motion. The procedure adopted is to start the transmitting drum by operating a switch which trips a magnetic clutch between the phonic motor drive and the drum. This clutch has only one tooth, and so the transmitting drum always starts in the same phase relationship to the drive. A contact on this drive makes once each revolution, and this sends the phasing signal down the line, which operates a magnetic clutch on the receiver. This clutch consists of a single pawl, bearing a fixed angular relationship to the start of the paper on the drum, which is made to engage with a 100-tooth ratchet wheel on the drive.

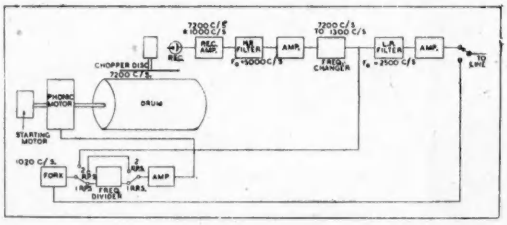
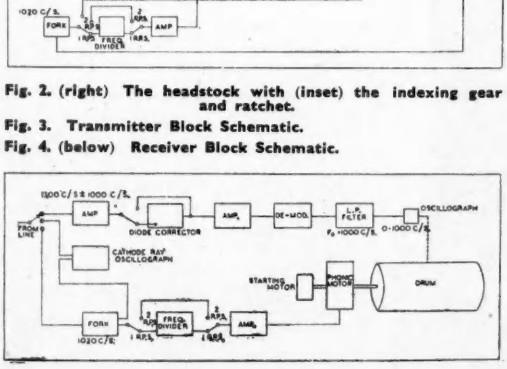
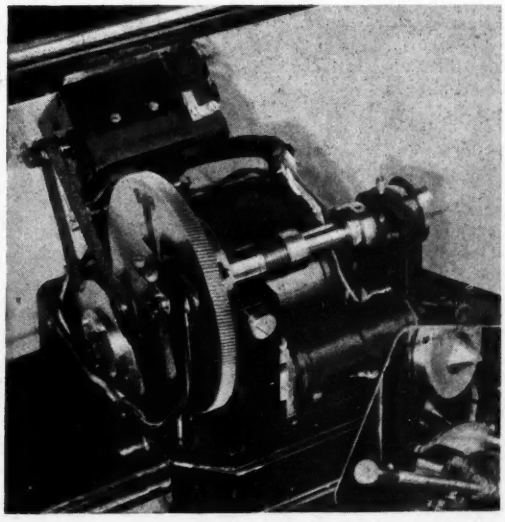



Fig. 2. (right) The headstock with (inset) the indexing gear and ratchet.

Fig. 3. Transmitter Block Schematic.

Fig. 4. (below) Receiver Block Schematic.



**TIME OF TRANSMISSION**

| Size of Picture | Drum Speed 2 Revs. per sec. | | | | Drum Speed 1 Rev. per sec. | | | |
|---|---|---|---|---|---|---|---|---|
| | Scanning 100 Lines/In | | Scanning 150 Lines/In | | Scanning 100 Lines/In | | Scanning 150 Lines/In | |
| | Mins. | Secs. | Mins. | Sec. | Mins. | Sec. | Mins. | Sec. |
| 10" × 8" | 6 | 40 | 10 | 0 | 13 | 20 | 20 | 0 |
| 11" × 10 (10⅜" × 10) | 8 | 20 | 12 | 30 | 16 | 40 | 25 | 0 |
| 1" of Traverse | 0 | 50 | 1 | 15 | 1 | 40 | 2 | 30 |
| 1 sq. in. of Surface | 0 | 4.8 | 0 | 7.2 | 0 | 9.6 | 0 | 14.4 |

Thus, the maximum phase error is not more than 3.6 degrees.

**Switching Facilities**

To simplify the setting-up operation special switching arrangements are provided. A rotary switch on both the transmitter and the receiver enables the following signals to be sent to line:—

(1) The actual picture.

(2) The phase signal for lining up the start of the picture.

(3) Artificial white.

(4) Alternate signals of artificial white and black (no signal) of four seconds duration each, repeated successively by cam-operated contacts.

(5) Similar successive signals of artificial white and stationary picture.

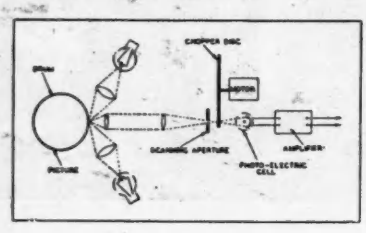
(6) 1,300 c/s. modulated by the transmitter tuning fork. This is particularly useful when working over carrier circuits where the fundamental carrier frequency is not accurately stabilised.

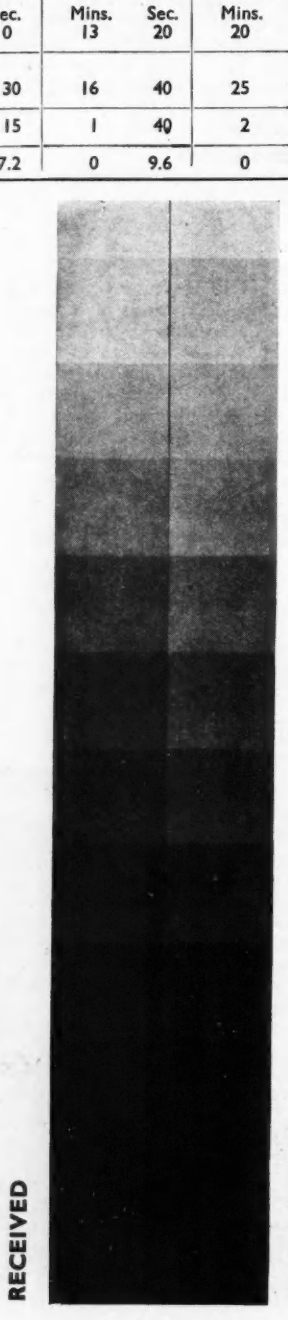
**Optical Systems**

The optical equipment of both instruments is carried on a vertical cast aluminium bulkhead and is readily accessible by removing a cover at the back. Optical details of the transmitter are shown in Fig. 6. Two lamps floodlight a small area of the drum, and the objective forms an image of this area on a fixed aperture which determines the size of picture element selected and behind which is a photo-cell. A chopper disc interrupts the light at 7,200 c/s. This disc with its driving motor and also the aperture and photo-electric cell are built into one unit. The photo-cell amplifier is also carried on the bulkhead, but is mechanically insulated from it by a shock-absorbing mounting. The receiver optical system utilises a Duddell oscillograph and is shown diagrammatically in Fig. 7 on Page 40. A window is provided for observing the deflection of the oscillograph without opening the instrument case.

**Fig. 7. (centre col.) Transmitter and Receiver tone density step wedge. The loss in the last tone before white could probably be rectified by a slight modification to the shaped tone-control aperture.**

**Fig. 6. (below) Transmitter Optical System.**



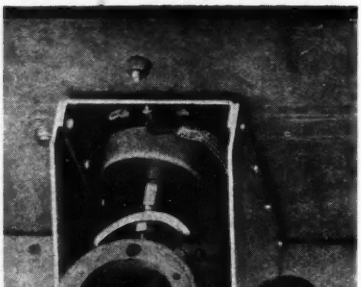



**Fig. 5. The Tuning Fork used for synchronisation. Note the rotatable magnet for frequency adjustment.**

The instrument is arranged for reception in normal daylight, and the actual drum camera is provided with a spring-loaded shutter. This cannot be opened until the camera is in position on the machine and the light-tight lid of the machine is closed down. A lever on the front of the machine is then turned; and the shutter automatically opened by means of a mechanical link; at the same time the light-tight cover is locked.

**Quality of Reproduction**

Some idea of the quality of received pictures can be obtained from the frontispiece, which is reproduced partly from the original picture and partly from the received negative. Perfection of reproduction is not simply a question of accurate scanning and precise adjustment of the optical system; the tone values of the picture must be reproduced exactly. Fig. 7 shows a comparison between transmitted and received tone density step wedges.

# 2—Cable & Wireless Facsimile Equipment

**A brief description of the Facsimile Equipment, designed by the Post Office Research Station, Dollis Hill, on behalf of Cable and Wireless Limited and manufactured by General Electric Company**

THE equipment is a self-contained unit for A.C. mains power supply, is built in console form and arranged for alternative transmission or reception. It is capable of transmitting or receiving about 5 photographs or sketches per hour.

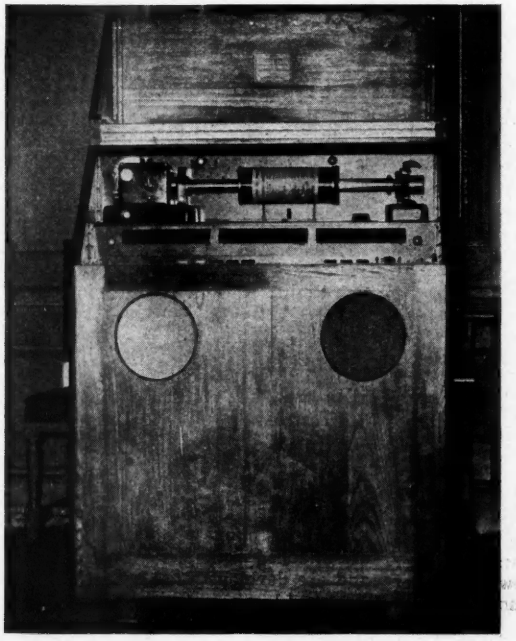
Transmission is by frequency modulation of an audio frequency carrier of 1,800 c/s. with a deviation of 200 c/s., the deviation to 1,600 c/s. representing black and that to 2,000 c/s. representing white, other tone densities being represented by intermediate frequencies. The FM signal, known as the sub-carrier may be transmitted over any line or radio-telephone channel by normal amplitude modulation. The advantages of frequency modulation in giving an improved signal-to-noise ratio and greater freedom from distortion are well known. Progress is being made in the development of frequency modulation of the R.F. carrier for facsimile and telegraphy, and it is probable for considerations of bandwidth alone this may become the normal method of transmission. For 60 r.p.m. facsimile the bandwidth required is about 1,200 c/s. for direct modulation and 5,000 c/s. for sub-carrier modulation.

The facsimile machine consists of a cylinder which rotates at a speed which is controlled by a quartz crystal and at the same time moves forward along a shaft and progressively exposes every part to a scanning light; the principle is similar to that of a screw-cutting lathe and scanning takes place in helical progression. For transmission the scanning light spot illuminates unit areas of the subject and for reception it exposes a photographic film. There are about 100 scanning lines per in. of drum travel and the definition is therefore of the order of 0.01 in. The drum rotates at 60 r.p.m.

The cylinder and lead screw are driven by an 1,800 r.p.m. synchronous motor which derives its power supply from a valve amplifier. The motor drive frequency source is a 108 kc/s. crystal, the output of which is fed to a regenerative frequency divider producing 10.8 kc/s., which in turn drives a second frequency divider to produce 1,800 c/s. The 1,800 c/s. voltage is used to drive a push-pull motor drive stage using two KT. 66 output tetrodes. In addition, the 1,800 c/s. is applied to the mirror galvanometer for interrupting the light beam on transmission. A branch circuit for the 10.8 kc/s. provides a carrier for the received signals in order to raise their frequency to a value which permits of convenient discriminator design.

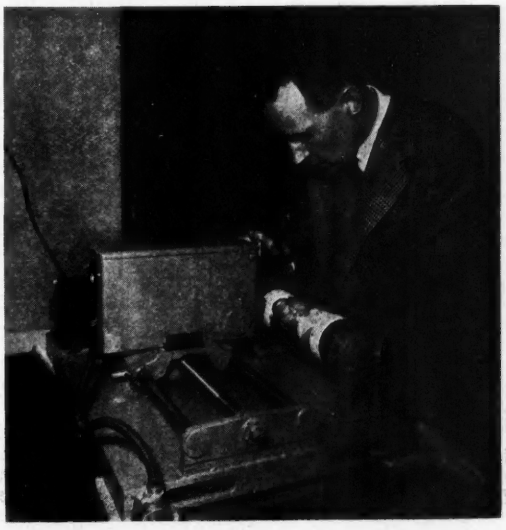
The lead screw is mounted inside a hollow shaft which has a longitudinal slot for the lead screw follower and the drum is mounted on the hollow shaft and made to move along by rotating the shaft and forcing the follower to run round the lead screw thread. The lead screw is driven at a slightly faster or slower rate than the hollow shaft and the rate at which the drum slides along the shaft will be determined by the difference in speeds. If the lead screw rotates at 54 r.p.m. or 66 r.p.m. the effective speed difference is 6 r.p.m. and with 10 turns per in. on the lead screw the drum will advance approximately 1/100 in. per revolution.

For ease of phasing the drum, a free wheel arrangement is fitted which permits of the speed of rotation being slightly increased or decreased:



**(left) Post Office—Cable & Wireless Transreceiver. The electronic equipment is housed in the console.**

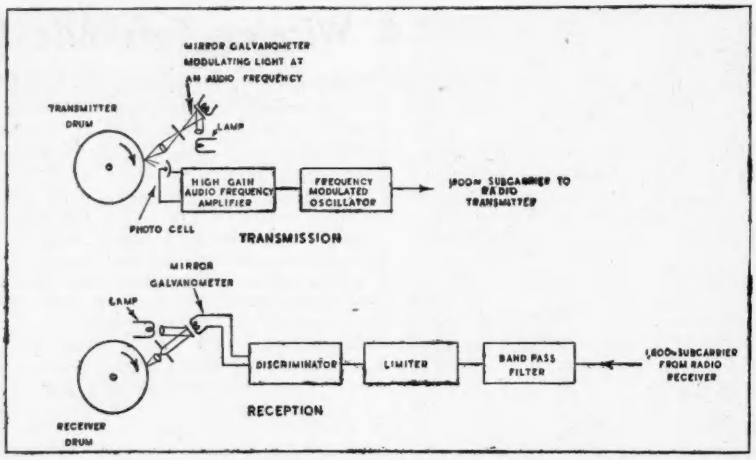
**(below) Transmitter also used by C. & W. Note the compact optical system which is traversed along in front of the drum.**



this enables the drum shaft to be correctly phased by observation of a rotating neon stroboscope image and ensures the drive will be taken up in the correct phase every time the drum is restarted for a new picture.

Scanning is normally by means of a left-hand helix for transmission and a right-hand helix for reception. It is necessary to scan in the opposite sense for reception in order to allow for the eventual reversal of the image when the positive print is prepared from the received negative.

For facsimile transmission it is an advantage to modulate the light source at an audio-frequency for subsequent ease of amplification of the photo-cell output. The design of a D.C. amplifier with the necessary degree of stability would present some difficulty, but by interrupting the light at a suitable audio-frequency a normal A.F. amplifier can be used.




**Schematic Diagram of System.**

The optical system consists of an exciter lamp, condenser lens, means of modulating the light, an aperture for fixing the ultimate shape and size of the light spot and a microscope objective for projecting the image on to the drum; irregularly reflected light from the illuminated area on the drum surface is picked up by twin photo-cells.

The mirror galvanometer for modulating the light is driven from the synchronous source driving the motor and the light falling on the photo-cell is therefore interrupted at an audio frequency and modulated by the picture intelligence.

The amplified amplitude-modulated carrier is rectified and the resultant D.C. is used to frequency modulate a beat oscillator which consists of two high-frequency oscillators, the frequency of one being fixed and the second modulated by the picture signal. The rectifier is a full wave diode rectifier which feeds into a low pass filter, the function of which is to remove the carrier ripple from the rectified signal, leaving only the picture modulation. The rectified signal is applied to the grid of a quadrature valve which is connected across the *LC* circuit of one of the H.F. oscillators.

The frequencies of the two H.F. oscillators are usually adjusted so that with no modulation applied to the reactance valve, *i.e.*, no output from photo-cell—black, the beat note is 1,600 c/s. When full modulation due to scanning white is applied the frequency of one oscillator is shifted to give a beat of 2,000 c/s. In order to produce the beat frequency the two H.F. frequencies are mixed in a frequency changer valve.

A band-pass filter is inserted between the beat oscillator and the control line to the radio transmitter to suppress noise or ripple and remove harmonic content. At the radio transmitting station the sub-carrier is amplified and after passing through a second band-pass filter similar to that fitted in the beat oscillator output, is fed to the modulator on a radio telephone transmitter.

After passing over the radio channel the frequency modulated sub-carrier is treated in the conventional fashion, being limited to remove all trace of amplitude variation and then passed to a frequency discriminator which reproduces an amplitude modulated audio frequency carrier. This A.M. signal is then rectified and utilised to operate a light valve which controls the amount of light falling on to a photographic film which is carried on the receiver drum, rotating at the same speed and in phase with the transmitter drum.

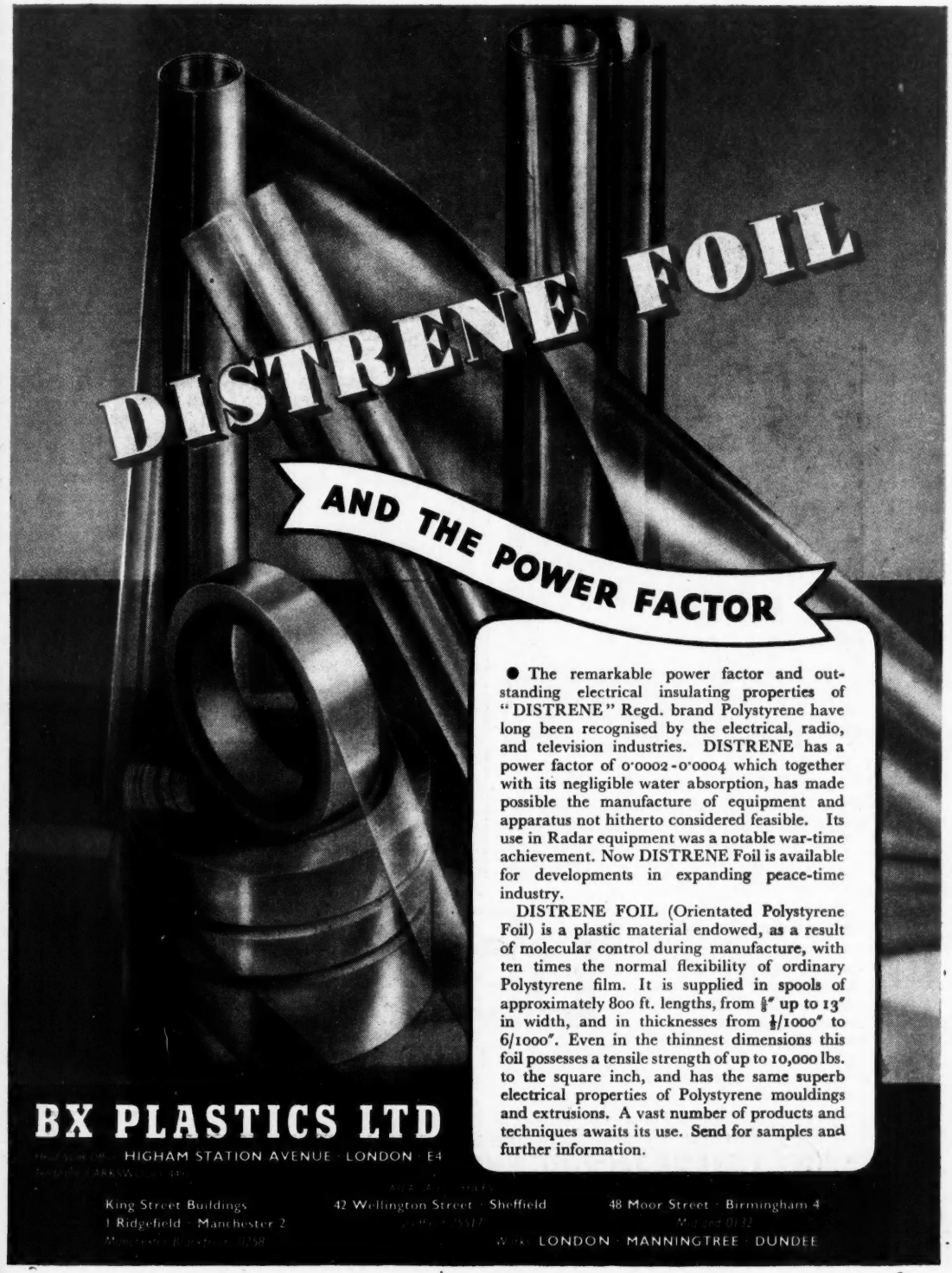
The received sub-carrier signal is first filtered in a band-pass filter, pass band 800 to 2,800 c/s., for the purpose of removing the noise and harmonic content which have been introduced during the course of the radio transmission.

After filtering, the sub-carrier is limited by a push-pull tetrode limiter and passed through a low pass filter which removes the harmonic content introduced by the limiting action. Normally the constant amplitude variable frequency voltage would then be applied to a phase or frequency discriminator for demodulation, but owing to the low carrier frequency of 1,800 c/s. it is a matter of some difficulty to design a discriminator which is linear over the required band and, in this case, the carrier frequency has been raised to 12,600 c/s. by modulating a 10,800 c/s. carrier derived from the 108 kc/s. crystal. After modulating, the carrier and the lower sideband are removed by means of a band-pass filter and the new carrier of 12,600 c/s. with the 200 c/s. deviation is applied to the discriminator. The equipment is designed to deal with maximum modulating frequencies of about 800 c/s. and the discriminator is therefore designed to have a linear characteristic over a band 11,600 to 13,600 c/s.

The demodulated signal is rectified and applied as a D.C. voltage to the mirror galvanometer, thus modulating the light beam and varying the amount of light falling on the photographic film which is wrapped round the drum. The same optical system is used as for transmission except that in this case the rectified facsimile signal is applied to the mirror galvanometer coils instead of the 1,800 c/s. "chopping" frequency derived from the crystal.

Photographic procedure is conventional; ordinary photographic films are attached to the drum for reception and are developed and contact prints prepared by normal means.

Fo

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# A Universal Oscillograph

By G. L. HAMBURGER
Dipl.Ing., A.M.I.E.E.

## Part II—*Conclusion.*

**Fig. 8. View of complete oscillograph opened to give access to components. The rectifier valves, etc., are enclosed in a special "heat compartment" seen at the side of the chassis on the right.**

AS already discussed in the introduction, only a simple one-stage amplifier was provided, which, however, is quite universal in its possibilities. Variation of amplification is achieved by altering the effective A.C. anode load resistance. This is done by sliding a 16 $\mu$F electrolytic capacitor along a constant resistance connecting anode to plus H.T., actually performing it in steps by means of a multiwafer switch $S_5$.

This scheme was adopted for the following reasons: A video amplifier should amplify any odd and peaky wave shape as faithfully as possible. A conventional volume control in the grid circuit would not accomplish this if it had the otherwise desirable impedance, because of the input capacity of the valve. Therefore, the gain must be controlled at a relatively low impedance, that is, in the anode circuit. On the other hand, a variable load resistor would also alter the D.C. working conditions of the valve. The adopted scheme, however, removes this disadvantage, and an anode volume control as applied in this case has the additional virtue of giving the maximum upper frequency response for the available gain. Lowering the gain with this scheme implies improving the upper frequency cut-off; this is depicted on the graph of Fig. 10 (p. 57.)

Gain variation and three types of operation are effected by 12 positions of the multiwafer switch $S_5$ (see Fig. 9).

In position 1 the amplifier is switched off.

In position 2 to 5 the amplifier is provided with 180 ohms cathode degeneration, which increases its signal handling capacity to about 4 volts peak-to-peak and straightens the valve characteristic. The gain rises from 5.5 in position 2 to 41 in position 5.

In positions 6 to 9 the cathode resistor is bypassed by 50 $\mu$F, thus providing a steady bias of about 2.5 volts, and a higher gain for the same anode load values as used previously, namely gain values from 12.5 to 96. Naturally the signal handling capacity is now reduced to about 1.7 volts peak to peak.

In positions 10 to 12 the screen voltage is lowered to about 75 volts, which in turn shortens the grid base of $V_1$ to about 1 volt. If, then, a sine wave of several volts is impressed on the control grid through a coupling condenser $C_{21}$ and a grid leak $R_{22}$ (see Fig. 9), a rectifying action takes place due to grid current which causes only the positive tips of the sine wave to be amplified. The anode voltage will then have a shape as indicated in Fig. 11a, and can be used for producing timing marks on the trace by applying it to the beam modulator of the cathode ray tube. An example of such timing marks as applied to a sine wave trace is shown in Fig. 11b.

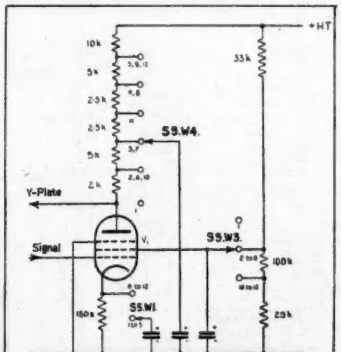


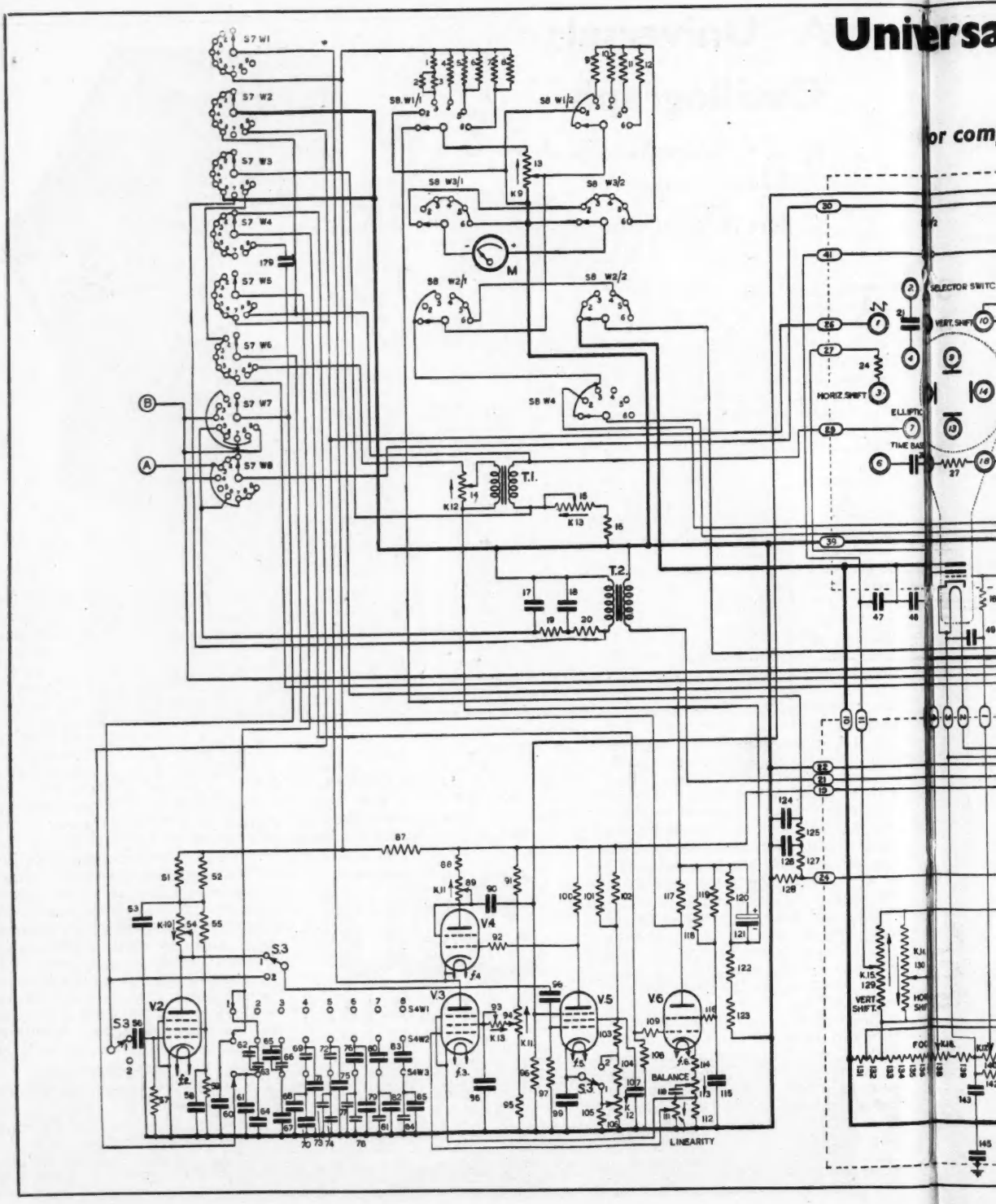

**Fig. 9 Basic circuit of amplifier, showing sensitivity adjustment.**

It must be pointed out that the absence of a volume control in the grid circuit of the vertical amplifier does not in fact restrict the versatility of the instrument. Indeed, a voltage of 4 volts peak-to-peak which is about the maximum the amplifier can handle without beginning to distort appreciably, can be quite comfortably observed directly on the screen when the cathode ray tube voltage is at its lowest value. Then the height of the oscillogram will be about 4 mm. as the maximum deflection sensitivity reaches one millimetre per volt at quite satisfactory brilliance.

### 2.5 Voltage Calibration and AC/DC Signal Operation

Almost as important as knowing the shape of a voltage wave is the knowledge of its voltage values. Ordinary A.C. meters fail to register

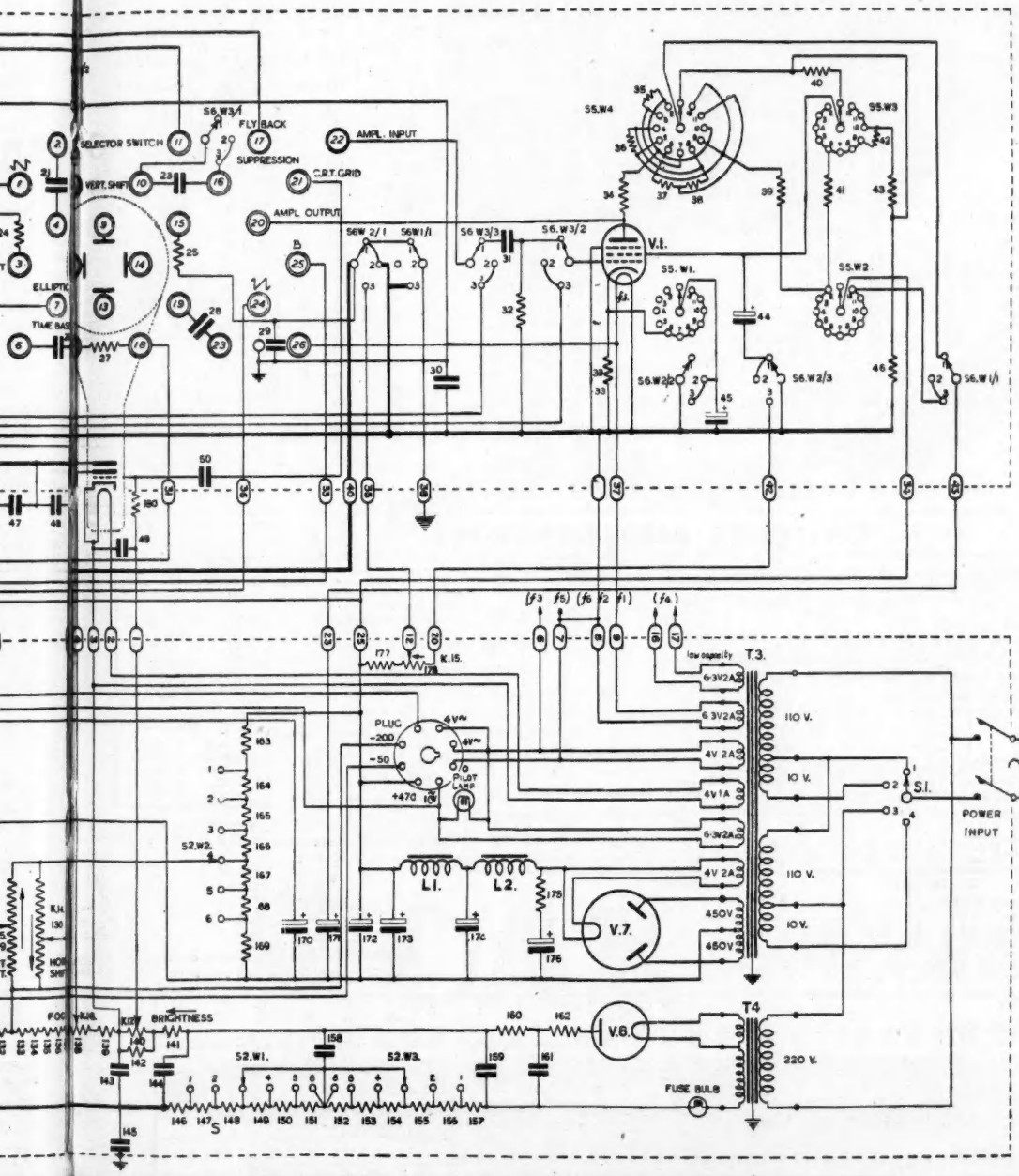
* Late of British Electrical Research Association.


S7 W1
S7 W2
S7 W3
S7 W4
S7 W5
S7 W6
S7 W7
S7 W8
S8 W1/1
S8 W1/2
S8 W3/1
S8 W3/2
S8 W2/1
S8 W2/2
S8 W4
M
T.1.
T.2.
V1
V2
V3
V4
V5
V6
S3
S4W1
S4W2
S4W3
BALANCE
LINEARITY
SELECTOR SWITCH
VERT. SHIFT
HORIZ. SHIFT
ELLIPTIC
TIME BASE

# Universal Oscillograph

## Complete Circuit Diagram

*For component values and switch positions see page 54*



# Universal Cathode Ray Oscillograph — Component Values

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | R | 1.5M. ½W. | 48 | C | 0.25μF. 350 V. D.C. | 97 | R | 1M. ½W. | 146 | R | 100K. 1W. in parallel with 250K. ½W. |
| 2 | R | 500K. ½W. | 49 | C | 0.5μF. 350 V. D.C. | 98 | C | 0.005μF. Mica | 147 | R | 100K. 1W. in parallel with 150K. ½W. |
| 3 | R | 1M. ½W. | 50 | C | 0.1μF. 2,000 V. D.C. | 99 | C | 50μF. Elec. 50 V. D.C. | 148 | R | 100K. 1W. in parallel with 250K. ½W. |
| 4 | R | 500K. ½W. | 51 | R | 25K. 1W. | 100 | R | 100K. 1W. in parallel with 100K. 1W. | 149 | R | 100K. 1W. |
| 5 | R | 150K. 1W. | 52 | R | 25K. 1W. | 101 | R | 50K. 1W. | 150 | R | 100K. 1W. |
| 6 | R | 500K. ½W. | 53 | C | 16μF. Elec. 300 V. D.C. | 102 | R | 50K. 1W. | 151 | R | 220K. 1W. in parallel with 1M. ½W. |
| 7 | R | 50K. 1W. | 54 | R | 2K. ½W. | 103 | R | 50K. 1W. | 152 | R | 220K. 1W. in parallel with 1M. ½W. |
| 8 | R | 250K. ½W. | 55 | R | 50K. 1W. in parallel with 50K. 1W. | 104 | R | 10K. 1W. | 153 | R | 100K. 1W. |
| 9 | R | 10K. 1W. 1% | 56 | C | 0.001μF. Mica | 105 | R | 1.5K. ½W. | 154 | R | 100K. 1W. |
| 10 | R | 100K. 1W. 1% | 57 | R | 60M. 1W. | 106 | R | 1K. ½W.C. | 155 | R | 100K. 1W. in parallel with 250K. ½W. |
| 11 | R | 500K. 1W. 1% | 58 | C | 12μF. Elec. 50 V. D.C. | 107 | C | 0.5μF. 350 V. | 156 | R | 100K. 1W. in parallel with 150K. ½W. |
| 12 | R | 1M. 1W. 1% | 59 | R | 5K. 1W. | 108 | R | 1M. ½W. | 157 | R | 100K. 1W. in parallel with 250K. ½W. |
| 13 | R | 50K. 5W. W.W. | 60 | C | 2μF. 500 V. D.C. | 109 | R | 500, ½W. | 158 | C | 0.25μF. 3,000 V. D.C. |
| 14 | R | 10K. 2W. W.W. | 61 | C | 0.0005μF. Mica | 110 | C | 50μF. Elec. 50 V. D.C. | 159 | C | 0.25μF. 3,000 V. D.C. |
| 15 | R | 200K. ½W. C. | 62 | C | 0.5μF. 350 V. D.C. | 111 | R | 200, ½W. C. | 160 | R | 100K. 1W. |
| 16 | R | 50K. 1W. | 63 | C | 1μF. 500 V. D.C. | 112 | R | 10, ½W. | 161 | C | 0.25μF. 3,000 V. D.C. |
| 17 | C | 0.01μF. 450 V. | 64 | C | 4μF. 450 V. D.C. | 113 | R | 250, 2W., W.W. | 162 | R | 10K. 2W. |
| 18 | C | 0.5μF. 350 V. | 65 | C | 0.1μF. 450 V. D.C. | 114 | R | 50, ½W. | 163 | R | 150K. 1W. |
| 19 | R | 250K. ½W. | 66 | C | 0.25μF. 350 V. D.C. | 115 | C | 16μF. Elec. 300 V. D.C. | 164 | R | 10K. ½W. |
| 20 | R | 5K. ½W. | 67 | C | 1μF. 500 V. D.C. | 116 | R | 500, ½W. | 165 | R | 10K. ½W. |
| 21 | C | 0.5μF. 350 V. | 68 | C | 0.1μF. 450 V. D.C. | 117 | R | 2K. 25W., W.W. | 166 | R | 10K. ½W. |
| 22 | R | 5M. ½W. | 69 | C | 0.05μF. 450 V. D.C. | 118 | R | 47K. 1W. | 167 | R | 10K. ½W. |
| 23 | C | 0.5μF. 350 V. | 70 | C | 0.05μF. 450 V. D.C. | 119 | R | 47K. 1W. | 168 | R | 10K. ½W. |
| 24 | R | 5M. ½W. | 71 | C | 0.01μF. 450 V. D.C. | 120 | R | 50K. 1W. | 169 | R | 100K. 1W. |
| 25 | R | 5M. ½W. | 72 | C | 0.01μF. 450 V. D.C. | 121 | C | 8μF. Elec. 400 V. D.C. | 170 | C | 16μF. Elec. 500 V. wkg. |
| 26 | C | 0.5μF. | 73 | C | 0.025μF. 450 V. D.C. | 122 | R | 20K. 1W. | 171 | C | 16μF. Elec. 500 V. wkg. |
| 27 | R | 5M. ½W. | 74 | C | 0.005μF. Mica | 123 | R | 50K. 1W. | 172 | C | 16μF. Elec. 500 V. wkg. |
| 28 | C | 0.5μF. 350 V. | 75 | C | 0.002μF. Mica | 124 | C | 50μF. 12 V. reversible | 173 | C | 16μF. Elec. 500 V. wkg. |
| 29 | C | 0.01μF. 450 V. | 76 | C | 0.002μF. Mica | 125 | C | 50μF. 12 V. reversible | 174 | C | 16μF. Elec. 500 V. wkg. |
| 30 | C | 0.01μF. 450 V. | 77 | C | 0.005μF. Mica | 126 | R | 5K. ½W | 175 | C | 16μF. Elec. 500 V. wkg. |
| 31 | C | 0.1μF. 400 V. | 78 | C | 0.001μF. Mica | 127 | R | 5K. ½W. | 176 | R | 50, 1W. |
| 32 | R | 10M. ½W. | 79 | C | 0.0005μF. Mica | 128 | R | 47, 1W. | 177 | R | 200K. 1W. |
| 33 | R | 270, ½W. in parallel with 500, ½W. | 80 | C | 0.0005μF. Mica | 129 | R | 2M. ½W. C. | 178 | R | 500K. ½W. C. |
| 34 | R | 2K. ½W. | 81 | C | 0.001μF. Mica | 130 | R | 2M. ½W. C. | 179 | C | 0.1μF. 350 V. |
| 35 | R | 5K. ½W. | 82 | C | 0.0005μF. Mica | 131 | R | 22K. 1W. | 180 | R | 5M. 1W. |
| 36 | R | 5K. ½W. | 83 | C | 0.0001μF. Mica | 132 | R | 47K. 1W. | 181 | | |
| 37 | R | 2.5K. ½W. | 84 | C | 0.0002μF. Mica | 133 | R | 47K. 1W. | 182 | | |
| 38 | R | 2.5K. ½W. | 85 | C | 0.0001μF. Mica | 134 | R | 100K. 1W. | 183 | | |
| 39 | R | 10K. 1W. | 86 | C | 0.5μF. 350 V. D.C. | 135 | R | 100K. 1W. | 184 | | |
| 40 | R | 3K. ½W. | 87 | R | 2.5K. 1W. | 136 | R | 100K. 1W. | | | |
| 41 | R | 100K. ½W. in parallel with 50K. ½W. | 88 | R | 1.5K. ½W. | 137 | R | 100K. 1W. | | | |
| 42 | R | 100K. ½W. | 89 | R | 3K. 2W., W.W. | 138 | R | 50K. 1W. C. | | | |
| 43 | R | 25K. ½W. | 90 | C | 0.1μF. 450 V. | 139 | R | 100K. 1W. | | | |
| 44 | C | 8μF. 275 V. | 91 | R | 47K. 1W. | 140 | R | 50K. 1W. C. | | | |
| 45 | C | 50μF. 12 V. | 92 | R | 100, ½W. | 141 | R | 2.5K. ½W. | | | |
| 46 | R | 5K. ½W. | 93 | R | 2K. ½W. C. | 142 | R | 50K. 1W. | | | |
| 47 | C | 0.25μF. 350 V. D.C. | 94 | R | 50K. 5W., W.W. | 143 | C | 0.5μF. 2,000 V. D.C. | | | |
| | | | 95 | R | 4.7K. 1W. | 144 | C | 0.25μF. 3,000 V. D.C. | | | |
| | | | 96 | R | 1M. ½W. | 145 | C | 2μF. 200 V. D.C. | | | |

# SWITCHES AND CONTROLS

**S.1. Mains tapping switch : 110, 120, 220, 230 volts.**
**S.2. Tube H.T. switch.**

| Stud ... ... ... | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| EHT in kV (across C 143) ... ... | 2.36 | 2.13 | 1.90 | 1.69 | 1.53 | 1.29 |
| Sensitivity in mm/volt | 0.44 | 0.50 | 0.57 | 0.67 | 0.75 | 0.9 |

**S.3. Time Base Control : 1—Continuous. 2—Single stroke.**

**S.6. Amplifier selector on panel.**

| Switch position ... ... | 1 | 1 | 2 | 3 |
|---|---|---|---|---|
| Type of signal ... ... | A.C. Large | A.C. Small | D.C. Large | D.C. Small |
| Feed signal into terminal | A | 22 | A | 22 |
| Link ... ... ... | 11 & 16 | 20 & 16 | 11 & 16 | 20 & 16 |

**S.7. Time Base selector switch.**

| Switch position ... | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Time base ... ... | off | S | S | S | S | S | S | O | O |
| Y-plate ... ... | A | A | A | B | A | 50 ~ | A+50~ | A | A |
| Sync. from ... ... | — | A | B | B | 50~ | 50 ~ | A | 50~ | B |

S — Sawtooth. O — Elliptical.

**S.8. Calibration Switch.**

| Switch position ... ... | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Voltage calibration range For D.C. or A.C. amplification ... ... ... | — 2 V | 0 | + 2 V | + 20 V | + 100 V | + 200 V |
| | Calibrate | Measure | Calibrate | | | |

| M | 200μA meter. | V1 | EF 50 |
|---|---|---|---|
| L1 | 10H, 150 mA. | V2 | EF 50. |
| L2 | 20H, 150 mA. | V3 | TSP 4 |
| T1 | Elliptic time base transformer. | V4 | KT 66 |
| | | V5 | TSP 4. |
| T2 | Miniature transformer No. 209. | V6 | KT 66. |
| | | V7 | UJ 5. |
| T3 | H.T. Transformer. | V8 | U 7. |
| T4 | E.H.T. Transformer. | C.R.T. | ECR 60. |

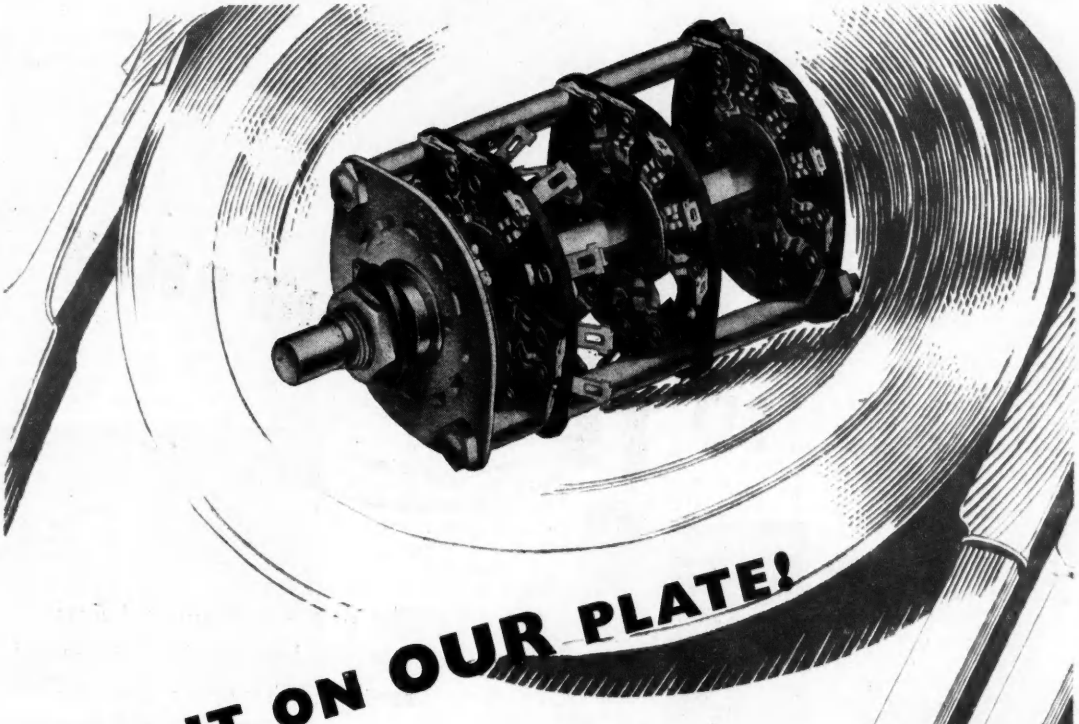
| Ganged Controls | |
|---|---|
| K11 : | R 94 + R 89 |
| K12 : | R106 + R 14 |
| K13 : | R 93 + R 15 |
| K15 : | R129 + R178 |

| Single Controls | |
|---|---|
| K 9 : | R 13 |
| K10 : | R 54 |
| K14 : | R130 |
| K16 : | R138 |
| K17 : | R141 |

| Standard Links | |
|---|---|
| 1 & 2 | 5 & 9 |
| 3 & 4 | 9 & 10 |
| 4 & 8 | 14 & 15 |
| 6 & 7 | 14 & 19 |
| 12 & 13 | 23 & 24 |

**S.4. Time Base Frequency control.**
**S.5. Amplifier switch on panel.**

| Switch position ... ... ... ... ... ... ... | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Amplifier Class ... ... ... ... ... ... | off | A | A | A | A | A | A | A | A | C | C | C |
| | | 170 Ω cathode degeneration | | | | Fixed bias (cathode resistor by-passed by 12μF) | | | | | | |
| A.C. Amplification ... ... ... ... ... ... | off | 5.5 | 20.5 | 31 | 41 | 12.5 | 48 | 71 | 96 | | | |
| | | Min → Max | | | | Min → Max | | | | Min → Max | | |
| 3 db down at ... Mc/s. | | 1.4 | 0.34 | 0.235 | 0.18 | 1.4 | 0.34 | 0.235 | 0.18 | | | |
| Max. R.M.S. input volts ... | | | | | | | | | | | | |
| D.C. Amplification ... ... ... ... ... ... | off | | | | | | | | | | | |
| Input range ... ... ... ... ... ... ... | | — 2 Volts to + 2 Volts | | | | — 2 Volts to zero | | | | | | |



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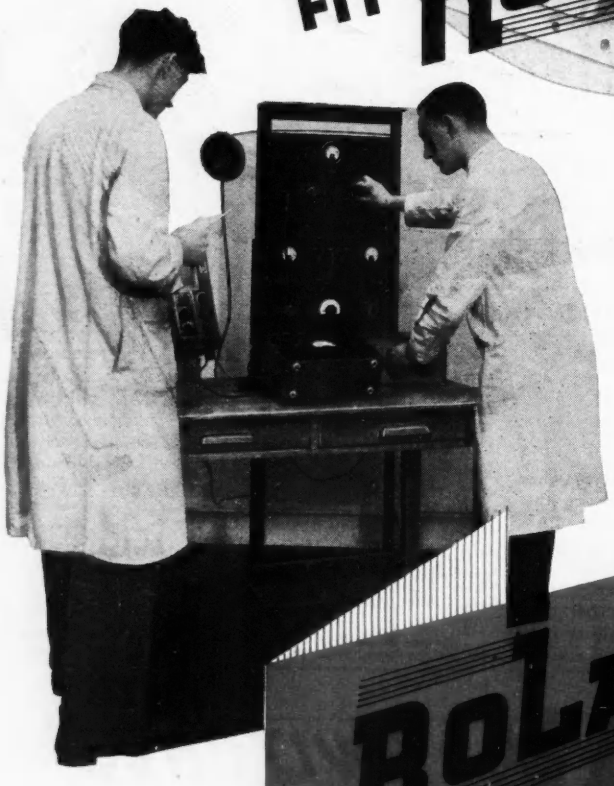

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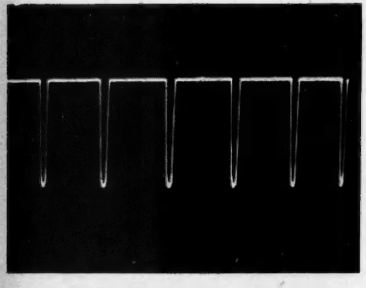
sensible values for anything deviating from sinusoidal form, quite apart from loading the test circuit to a degree which is undesirable. One can, of course, calibrate the screen of the cathode ray tube in terms of voltage, and then measure the voltage wave in terms of length. However, this method suffers from the serious defect that the sensitivity of the tube depends upon the exact value of the mains voltage; further, it varies from sample to sample of the tube used, and also somewhat depends on the brightness setting owing to the regulation of the E.H.T. power pack.

It was, therefore, decided to incorporate a high-class meter in the cathode ray oscilloscope and use it in the following manner:—



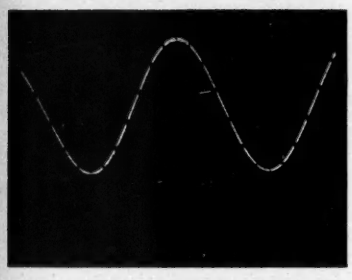


**Fig. 11a. Pulses produced by special adjustment of amplifier, and (Fig. 11b) their use as timing marks on a sine wave.**

A special variable shift voltage was derived from the H.T. power pack; it was measured by this meter and applied to the lower Y-plate. With the ordinary shift applied to the upper Y-plate the wave to be measured can be set to any place on the screen. Any voltage difference between two points of the wave can then be determined by placing the lower potential point on a fixed horizontal hairline across the screen by means of the ordinary vertical shift, and then by shifting the wave downwards with the calibration shift applied to the lower Y-plate until the upper potential point comes to rest on the horizontal hairline. The

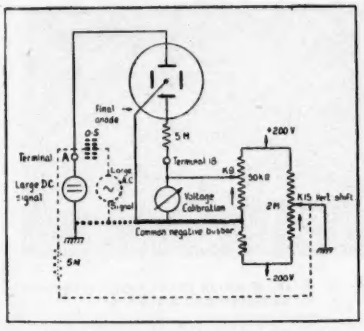


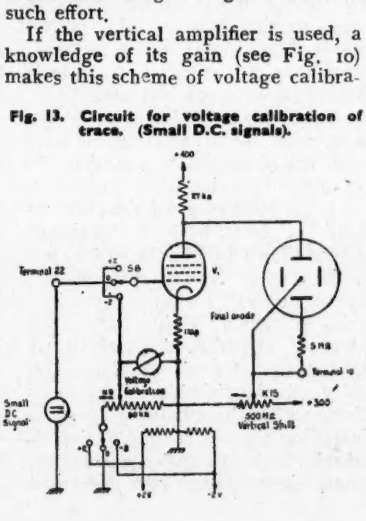

**Fig. 12. Circuit for voltage calibration of trace using shift potential. (Large signals).**

meter reading then indicates the true potential difference between the two points, and the measurement is thus performed with the accuracy of the meter. It is inherently independent of variations of mains voltage and tube sensitivity. The outline of this scheme is indicated in Fig. 12.

It may be mentioned at this juncture that the ordinary shift potential must always be applied to the plate that carries the signal. One has then achieved that maximum focus quality will always prevail in the centre region of the screen whatever the shift potential. If, however, a shift potential is applied to the plate not carrying the signal (as in the case of the calibrated shift) a defocusing effect will take place, deforming the spot into an ellipse. This defocusing effect arising from higher calibration shift voltages could be avoided by a special scheme at the cost of a separate negative power supply, but it was not found disturbing enough to warrant such effort.

If the vertical amplifier is used, a knowledge of its gain (see Fig. 10) makes this scheme of voltage calibra-

**Fig. 13. Circuit for voltage calibration of trace. (Small D.C. signals).**




tion also applicable for small signals.

Another important application is the indication and measurement of D.C. voltages. A special multiwafer switch $S_6$ on the desk panel permits a changeover from A.C. to D.C. observation. It performs quite a number of functions and essentially changes the dotted circuit of Fig. 12 into that shown by the full lines. The most important alteration is that the whole negative bus-bar of the total circuit is now floating with respect to the earthed chassis and case. Its potential can be varied "above and below" earth by the ordinary vertical shift potentiometer, the slider of which is now earthed. It is evident from this figure that the scanning line representing the D.C. signal can again be shifted by the ordinary and the calibrated shift control in the same manner as described for the A.C. case. D.C. measurements can thus be carried out at practically infinite impedance, for the 5 megohm Y-plate leak is removed as well as the coupling condenser by the switch $S_6$, and the stray electron current to the deflector plates is so small that it may well represent resistances of the order of medium quality insulation. Indeed, potentials of charged capacitors can quite comfortably be measured with this arrangement.

Switch $S_6$ has a third position for amplified D.C., and thus extends the range of measurement into the millivolt region. 50 millivolts, representing one division on the meter, can be measured without effort with a loading corresponding to the grid current of the E.F.50 vertical amplifier tube at minus 2.5 volts grid bias. The principal scheme of this new measuring arrangement is shown in Fig. 13. However, it must be borne in mind that all these different circuit arrangements are automatically achieved by the multiwafer switch $S_6$, and consequently do not burden the operator with their apparent complexity.

The method adopted is that of substituting the unknown D.C. signal fed to the vertical amplifier by a measurable voltage which produces the same anode potential on the amplifier tube and therefore the same beam deflection. The ordinary vertical shift, though again being operated by the same control knob $K_{15}$, effectively varies the positive busbar of the now floating E.H.T. pack between earth and plus H.T. so that the final anode voltage of the cathode ray tube and the lower deflector plate can be given the same positive potential as the upper

deflector plate, thus bringing the trace back to centre again. Having done this with the unknown D.C. signal in the input, the measurement procedure merely consists of switching the calibration range switch $S_8$ from zero to plus or minus 2 volts (according to whether the signal was positive or negative with respect to earth) and adjusting the calibration control K9 such that it brings the trace back to centre. Then calibration voltage and unknown signal are equal in magnitude and the meter-reading indicates the signal.

It was found experimentally that a source impedance of one megohm produces an error in the order of 10 millivolts, which, however, is a substantially constant quantity all over the scale. For lower source impedances the error diminishes rapidly.

### 2.6 The Selector Switch S7

This nine-position switch has been incorporated to speed up the change-over of certain circuit arrangements necessary for certain types of observation, and permits the use of a number of convenient combinations of signal and sync. voltages, and the two types of time bases. It reduces the number of input terminals on the front panel to two, namely, terminals A and B. The $S_7$ table on p. 54 gives a survey of the switch positions corresponding to the dial marking.

The first row indicates the type of time base used where the symbol S stands for the saw tooth time base, and O for the elliptical time base. The second row shows which voltage is applied to the upper Y-plate and hence delineated by the time base, and the third row tells from which voltage the time base is synchronised. In a general case two different signals appearing at two different points of the apparatus or circuit set-up investigated will be fed to terminals A and B. Usually A will be the signal which it is desired to observe, whereas B may be the voltage at some other point in the circuit which originated A. Therefore switching, for instance, from position 3 to 4 will give an opportunity to view both signals alternatively and measure the phase shift between A and B. In both cases the time base is locked to B, and therefore either A or B appears on the screen on a B time scale. In position 5 the time base

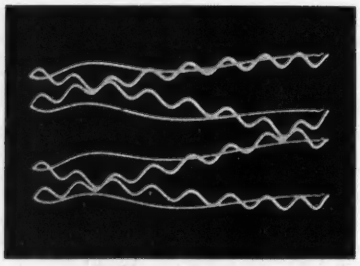


Fig. 14. Trace showing use of mains frequency as calibration standard.




Fig. 15. Basic circuit of the elliptical time base.

can be locked to mains, which is very useful for certain hum investigations, etc.

### Mains Calibration of Frequency

Position 7 offers a rather unusual feature. It permits the spot calibration of a variable frequency oscillator in terms of mains frequency—which once upon a time used to be a fairly accurate frequency standard—by adding the 50 c/s. and the unknown waves on the screen. The calibration is then carried out as follows: Suppose an A.F. of 2,000 c/s. is to be checked against 50 c/s. mains, *i.e.*, there are 40 A.F. cycles to one mains cycle. If the time base is now synchronised to the A.F. so that, for instance, 10 cycles of A.F. come to one saw-tooth sweep (of then 200 c/s. repetition frequency), a stationary pattern shown in Fig. 14 will appear on the screen. The 50-cycle wave is broken up into 200/50 = 4 portions, each stretching right across the screen. Therefore there are 4 A.F. wave trains traced on the screen easily distinguishable from each other, and each containing 10 cycles (including those occurring during the flyback). The 10 cycles are easy to count, since even if the pattern is slightly drifting due to the A.F. not being a precise multiple of 50 c/s., it is not the wave trains that wander in horizontal direction, for they merely appear as if wrapped round a cylinder slowly rotating around a horizontal axis. Thus the number of wave trains and the number of cycles can easily be counted, namely 4 and 10, and the desired frequency is then $4 \times 10 \times 50 = 2{,}000$ c/s. Fig. 7b (Part 1) shows what would appear on the screen if selector switch $S_7$ were in position 8, namely, when the 2,000 c/s. applied to A were delineated against an elliptic time base derived from 50 c/s. mains. It is tedious enough to count the waves on the photograph, but it is next to impossible to do so on a drifting oscillogram. The method of switch position 7 can therefore be used for spot calibrations of the frequency dial of an oscillator up to about 10,000 c/s.

Finally, if the switch is in position 9, an elliptic trace is produced from a sinusoidal voltage fed into B and a signal A can be delineated against this time base.

### 2.7 Elliptical Time Base

The principle of the elliptic time base is shown in Fig. 15. The 90° phase shift between X and Y plate voltages required for producing an elliptic trace is obtained by capacity and resistance in series, their joining point being earthed. The sum voltage of this series RC - combination must then necessarily be supplied via a transformer, the primary of which is fed from the power amplifier valve $V_6$ on the grid of which a pure sine wave is impressed. To avoid DC magnetisation of the transformer, a bridge circuit was employed to buck up the plate potential of $V_6$. $R_{117}$ serves as amplitude control, and is ganged with $R_{106}$, the amplitude control for the saw tooth time base, so that the front panel knob assigned for amplitude control serves for both types of time bases. The circuit alterations necessary to use $V_6$ for the two purposes, to feed the right potentials to the deflector plates, etc., are all carried out by a multiwafer switch $S_7$, thus inflicting no complications upon the operator. The frequency of the elliptic trace can either be 50 c/s. derived internally from the mains or any external frequency between 50 and 60,000 c/s.; also this choice is performed by $S_7$.

### 2.8. The Desk Panel

For laboratory use it is sometimes essential to be able to use the cathode ray tube alone, when, for instance, special time bases are to be connected, D.C. potentials to be applied, etc. In all these instances it is necessary to be able either to isolate the deflector plates completely from the attached cathode-ray oscilloscope circuits, or to remove the time base connexions while retaining the shift facilities and the R.C. coupling circuits of the deflector plates. A terminal board comprehensively arranged and with the circuit connexions to the terminals engraved on the desk panel was considered the best solution for the task set out. For normal operation the terminals are connected with brass links in a standard fashion as indicated in Fig. 16 and the presence of those terminals can be ignored.

To ensure shortest connexions to the deflector plates and easy accessibility, this terminal panel was fixed on top of the cathode-ray tube base, *i.e.*, at the top back of the oscilloscope. For easier handling it was made to tilt upwards as shown in the photograph of the complete instrument (Part I). If not in use it can be retracted into horizontal position and the lid carrying the instruction sheet on its inside can be closed to be level with the top of the cathode-ray oscilloscope case.

It may be mentioned in this connexion that the video amplifier with its 12-position switch and the A.C./D.C. switch are also accommodated on the desk panel.

### 2.9. Mechanical Design

Apart from the retractable desk panel there are two more unorthodox features about the layout and mechanical design of this instrument.

(a) The apparatus consists of two main chassis, one above the other, both chassis being hinged together at the back. Connexions from the bottom chassis containing the power pack to the top chassis containing the time base, calibration circuits, etc., and the tube are made by short flexible leads situated near the hinge. The top chassis can thus be swung back while the apparatus is working. This proved invaluable for the construction as well as for possible servicing of the cathode-ray oscilloscope, as all parts are very easily accessible. Fig. 8 gives a view of the oscillograph in the open condition.

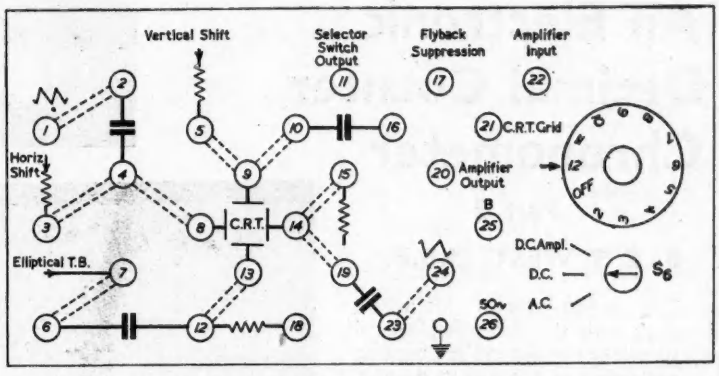



**Fig. 16. Layout of desk panel, showing links. The selector switch S5 and amplifier switch S6 are shown on the right.**

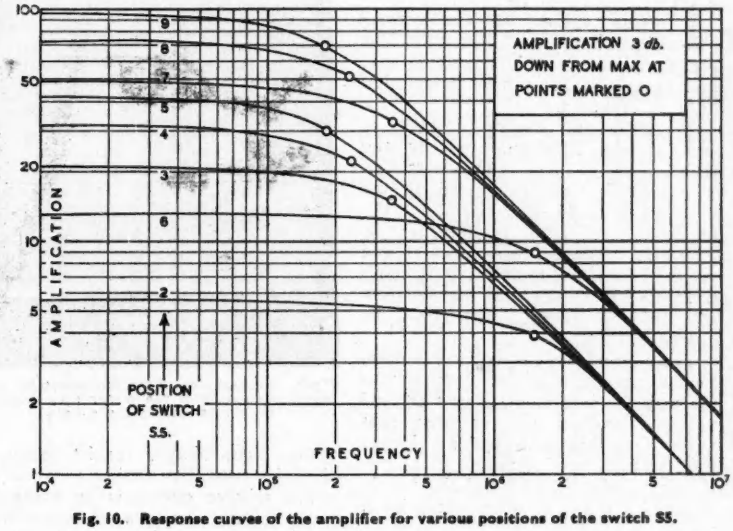


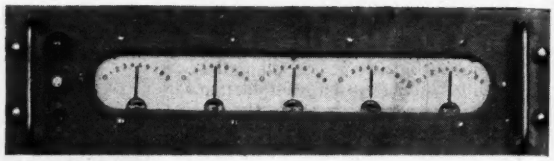

**Fig. 10. Response curves of the amplifier for various positions of the switch S5.**

(b) Since the four time base valves $V_3$, $V_4$, $V_5$ and $V_6$, together with the anode load $R_{117}$ of $V_6$, dissipate power in the order of 60 to 70 watts, it was found inadvisable to allow this heat to get distributed throughout the apparatus; in other words, to tolerate too high a temperature level within the enclosed apparatus. A special heat duct system was evolved which completely encased the mains rectifier, the valves and the power load resistance $R_{117}$. It can be seen in Fig. 8 where the outside case has been taken off. A rectangular hole at bottom and top of the side wall of the case allow for the passage of air through the heat duct system. The draft and therefore the cooling produced by the funnel effect of the heat duct system is considerable, and, in fact, the rest of the apparatus remains quite cool even after long hours of operation.

The instrument was developed under the auspices of the E.R.A. in connexion with the oscillographic investigation of radio interference (4) and the author is indebted to the director of the British Electrical and Allied Industries Research Association for permission to publish this paper.

[1] O. S. Puckle: Time Bases, Chapman & Hall.
[2] A. C. Clarke; Linearisation Circuits, *Wireless Engineer*, June, 1944.
[3] G. L. Hamburger; Letter to the Editor, *Wireless Engineer*, February, 1945.
[4] E.R.A. Reports M/T.83 and M/T.86.

# An Electronic Decimal Counter Chronometer



## Part 2

By S. S. WEST, M.B.E.*

**The second part of this article deals with the pulse-shaping and switching circuits and the method of indicating the count directly by means of meter indications**

THE ' scale of two ' circuit comprises valves *34* and *35* of Fig. 1 (Jan. issue). The arrangement adopted is conventional and for this reason a brief description only is provided.

The grids and anodes of valves *34* and *35* are interconnected by the resistances *37* and condensers *40*. The cathodes are connected to the common bias resistance *42* and the anodes have load resistances *36*. The grid leaks are resistances *38* and *39*, the resistance *39* of valve *35* being connected to a point on the negative H.T. lead for reasons which will be described later.

The ' scale of two ' counter is connected to the scale of five counter through the intermediate or ' driver ' valve *1* and it will be seen that valve *33* serves as a driver valve to the ' scale of two ' counter.

The ' scale of two ' and the ' scale of five ' circuits together comprise a ' scale of ten ' unit.

### Pulse Shaping Circuit

So far the ' scale of ten ' circuit has been described without any particular reference to what it is intended to count. Actually, the circuit is capable of counting any series of events which may be converted into electrical impulses, provided only that such events do not occur at a rate exceeding 100,000 per second. There is no lower limit to the counting speed and it is not necessary that the events should occur at regular intervals. It is, however, necessary that the counter be supplied with pulses of a prescribed shape. To convert any arbitrary input signal to the waveform required by the counter a pulse-shaping circuit is employed.

**Fig. 9. General view of the Chronometer, and above) a close-up of the meter rack showing the direct reading of the dials.**

The pulse shaper consists essentially of a two-valve ' trigger circuit.'† The trigger circuit is an arrangement giving an output waveform which consists of discontinuous steps even though the input waveform may be continuous, the only relation between the output and the input waveforms being that the timing of the discontinuities is determined by the time instants at which the input waveform crosses definite critical values. The circuit uses two valves. One such ' trigger pair ' is used as a pulse shaper, and two trigger pairs are used in the switching circuit. This is described later.

For purposes of explanation a skeleton circuit of a trigger pair is shown in Fig. 5a. Two pentodes *1* and *2* have their cathodes connected together and to the common bias resistance *4*. The anode circuit of valve *1* is coupled to the grid of valve *2* by the resistances *5*, *6* and *7*, *6* having a condenser *8* connected across it. The output terminals 10 are connected across the anode of resistance *9* of valve *2*.

Resistances *5*, *6* and *7* provide a coupling from the anode circuit of valve *1* to the grid circuit of valve *2* and the common cathode resistance *7* provides a further coupling from valve *2* to valve *1*. This closed regenerative path will be unstable if the gain round the loop exceeds unity, which will be the case if both valves try to come into operation at the same time. The system therefore has two states of stable equilibrium in which either valve is operative and the other inoperative, and a transient state of instability when both valves are operative. Whenever it is produced the unstable state can have only an exceedingly brief duration, for one or other of the valves is quickly driven beyond cut-off and a new state of stability is found.

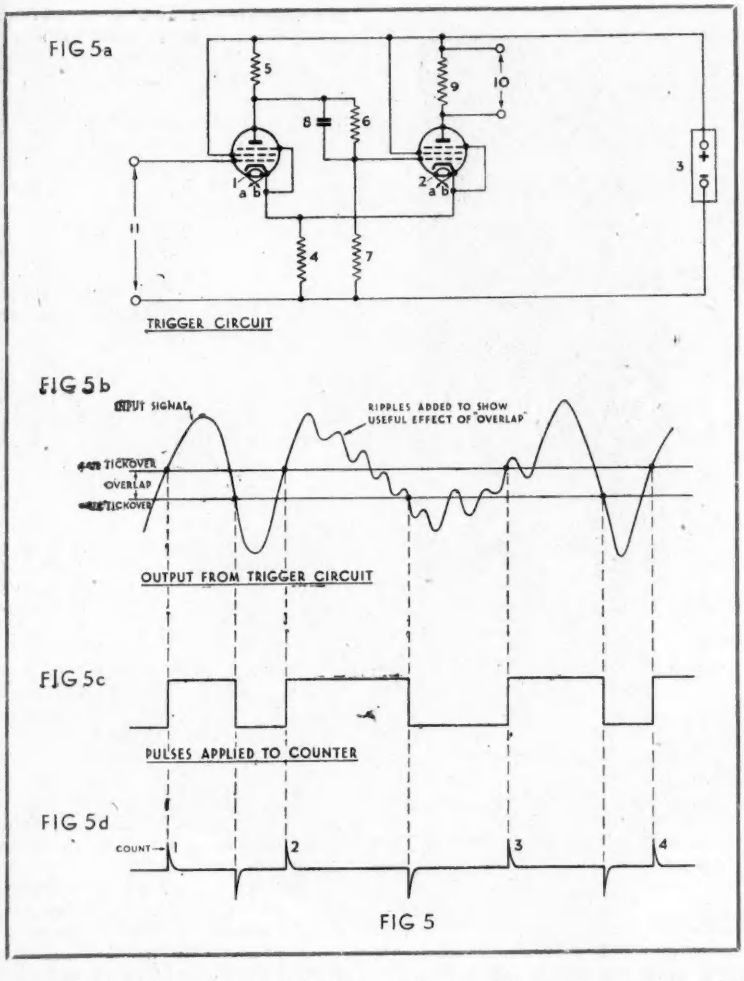
Suppose that initially valve *1* is inoperative. Resistances *5*, *6* and *7* then determine the potential on the grid of valve *2* and hence the potential of the common cathode point. This, in turn, fixes the potential which would be required on the grid of valve *1* to bring this valve into operation.

Due to the presence of condenser *8* the coupling from the anode circuit of valve *1* to the grid of valve *2* is considerably greater for high frequencies than for D.C., so that only a small mutual conductance in valve *1* is sufficient to raise the regenerative feedback to the value required to produce instability. If the grid of valve *1* is raised from a negative value to the critical value required to give this conductance the system suddenly ' ticks ' over to the condition in which valve *2* is inoperative and valve *1* is passing its full current.

When valve *1* is operative the D.C. coupling from its anode circuit applies a negative signal to the grid of valve *2*, while the common cathode potential is determined by the potential applied to the grid of valve *1*. If, therefore, the grid of valve *1* is taken some way negative a point is

* Cinema-Television, Ltd.

† Br. Pat. No. 552,301




reached at which valve *2* can come into operation again. When the conductance of valve *2* reaches a certain critical value the feedback again becomes sufficient to produce instability and the circuit ticks back to its original condition.

In either condition of stability one or other of the valves is inoperative so that the anode current of valve *2* is not dependent on the value of the signal applied to the grid of valve *1*. If the very small initial current required to develop instability is ignored it will be seen that the anode current of valve *2* can have one of two fixed values, normal or zero, and will change abruptly from one to the other when the signal applied to the grid of valve *1* reaches the appropriate 'tick over' point.

The positive and negative 'tick over' points can never be quite coincident, the voltage difference between them being in the nature of a 'backlash' or 'overlap.' If required, a circuit of this type can be designed to have a very small overlap, but for the present purposes the circuit proportions have been chosen to give a comparatively large overlap for reasons which are later described.

The circuit of Fig. 5a may be used as a pulse shaper by applying the signal to the grid of valve *1*. Fig. 5b shows a signal of arbitrary shape crossing the positive and negative tick over levels indicated as + ve and − ve. Fig. 5c shows the output signal on the anode of valve *2* which is suitable for driving the scale of ten counter unit. Fig. 5d shows the signal on the first driver valve of the counter due to the grid circuit coupling constants employed. The peaks marked *1, 2, 3, 4* are recorded by the counter which operates on the positive wavefronts. The diagrams show that the overlap performs a useful function by preventing minor fluctuations in the signal from tripping the circuit and influencing the counting.

### Switching Circuit

For use as a chronometer the counter must be provided with a standard oscillator and means for switching the oscillation on to the counter which can then count the number of cycles which occur during the time interval to be measured. Almost any kind of oscillator could be used, but since the long-time accuracy of the chronometer is determined by the oscillator stability the choice is practically limited to crystal or fork controlled oscillators.

For obvious reasons the oscillator must be running continuously during measurements and an electronic switching unit is required to connect and disconnect the oscillatory drive for the counter. The switch unit described herein is arranged to be started and stopped by electrical impulses of negative polarity supplied to it through separate starting and stopping channels. The manner in which the starting and stopping pulses are generated will depend on the nature of the events being timed. In the vast majority of cases it is a simple matter to arrange that the start and finish of the time interval are transmitted in the form of negative impulses to the switching unit.

There is always the possibility, especially when the pulses are generated by mechanical contacts, for the correct starting and stopping pulses to be followed by other, spurious, pulses. It is desirable therefore that the switching unit should respond only to the first pulse received on each channel. This result is achieved by the use of two trigger circuits of the type already described.

These two trigger circuits together with the pulse shaping circuit are assembled on a common chassis. See Fig. 6. A circuit diagram of the complete switching unit is given by the Fig. 7.

The starting circuit for the chronometer is connected to the grid of valve *9* which forms a 'trigger pair' with valve *18*. The stopping circuit is connected to the grid of valve *32* which forms a second trigger pair with valve *39*.

The oscillatory or other drive is connected to the grid of valve *50* which together with the valve *57* forms a trigger pair, in this case used as a pulse shaping circuit as already described.

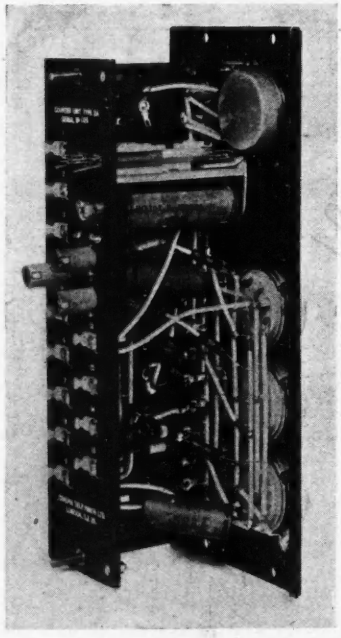
The grids of valves *18* and *32* are also connected to the re-setting switch so that when re-setting valves *9* and *39* of the pairs are in an operative condition.

Suppose the unit is reset and ready for operation. Valve *32* is inoperative and so is insensitive to any negative impulses which might arrive in the stopping circuit. Valve *9* is, however, operative so that the first negative pulse which arrives in the starting circuit will cause the trigger pair *9-18* to 'tick over,' valve *18* becoming operative instead of valve *9*. Valve *9*, having been cut off, becomes insensitive to any further negative pulses in the starting circuit.

The start of current in valve *18* transmits a large negative pulse to the grid of valve *39* and changes over the trigger pair *32-39* so that valve *32* becomes operative and valve *39* inoperative. Valve *32*, being operative, is now sensitive to negative pulses in the stopping circuit.

When the stopping pulse is received the trigger pair *32-39* ticks over again. Valve *32* again becomes insensitive to any further negative pulses and valve *39* becomes operative again.

So far only negative pulses have been considered. It is also necessary to consider the possible effects of spurious positive pulses. To minimise the possibility of faulty operation due to spurious positive pulses the trigger pairs *9-18* and *32-39* are arranged to have a large overlap (about 20 volts) and the normal bias



**Chassis containing pulse-shaping and trigger circuits.**

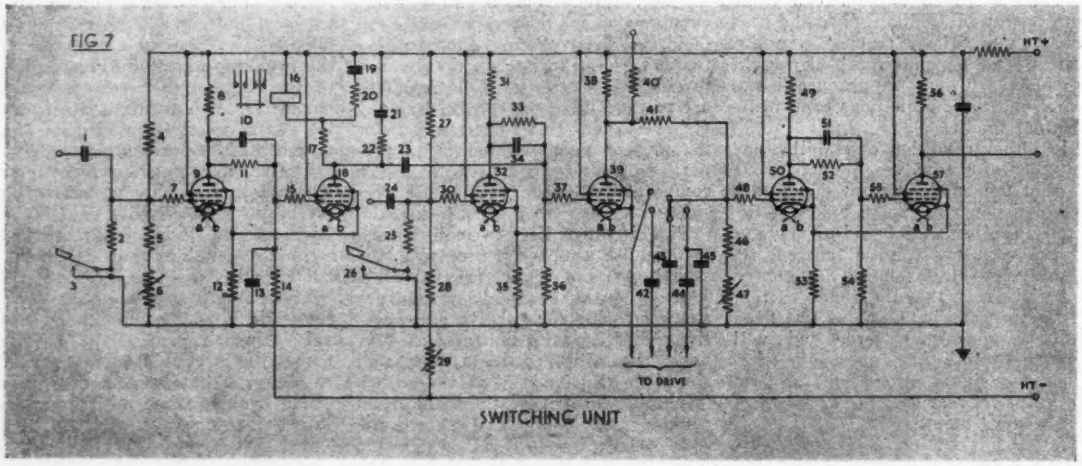
(on valve *9* or *32*) is only slightly (about 3 or 4 volts) above the negative tick-over point. Thus while correct operation can be obtained with quite a small *negative* pulse (say, 5 volts) it will take over 15 volts *positive* pulse to produce faulty operation. Now although it may be impossible to prevent the occurrence of small positive pulses it is relatively easy to arrange the starting and stopping circuits so that they are incapable of producing a spurious pulse which is both larger than normal and of reversed polarity. It may be said therefore that the system is virtually immune from faulty operation due to spurious pulses.

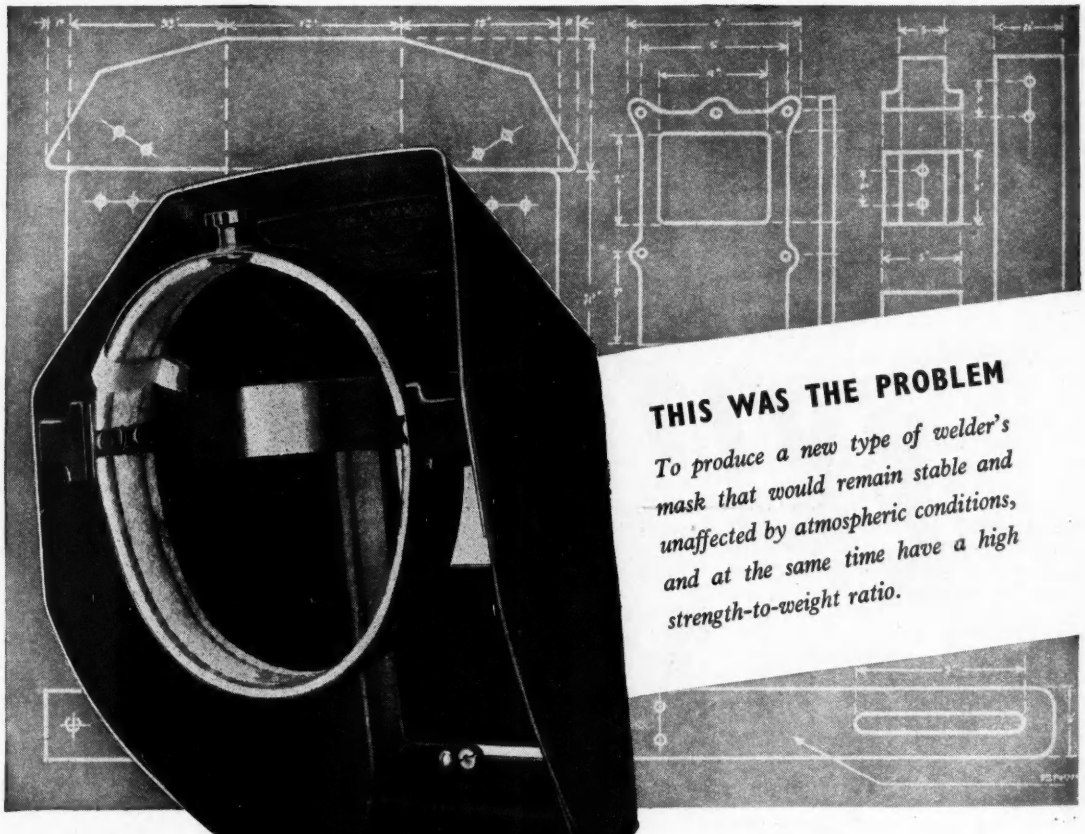
Returning to the normal operation of the circuit it will be seen that both before the starting pulse is received and after the stopping pulse has been received valve *39* is passing current, but that in the interval between the receipt of the starting and stopping pulses, *i.e.*, during the time interval to be measured, valve *39* is cut off. The anode circuit of valve *39* is D.C. coupled to the grid of valve *50*. When valve *39* is cut off the bias on valve *50* is such that the input drive signal crosses both the tick-over points of the trigger pair *50-57* which operates as a shaping circuit. The square waveform generated on the anode of valve *57* is applied to the counter. When valve *39* is operative the potential on the grid of valve *50* is reduced so that the drive signal no longer crosses the positive tick-over point and shaping does not occur, valve *57* remaining continuously operative.

The square wave is therefore started up on receipt of the starting pulse and shut down on receipt of the stopping pulse, the number of square waves occurring in the interval can then be recorded by the counter.

Careful attention has been paid to the design of the circuit associated with the grid of valve *50* to ensure that any systematic error introduced by the starting and stopping operation shall be of negligible magnitude. It is, of course, inherent in the counting principle that the answer can be given only to the nearest unit (*i.e.*,

FIG 7





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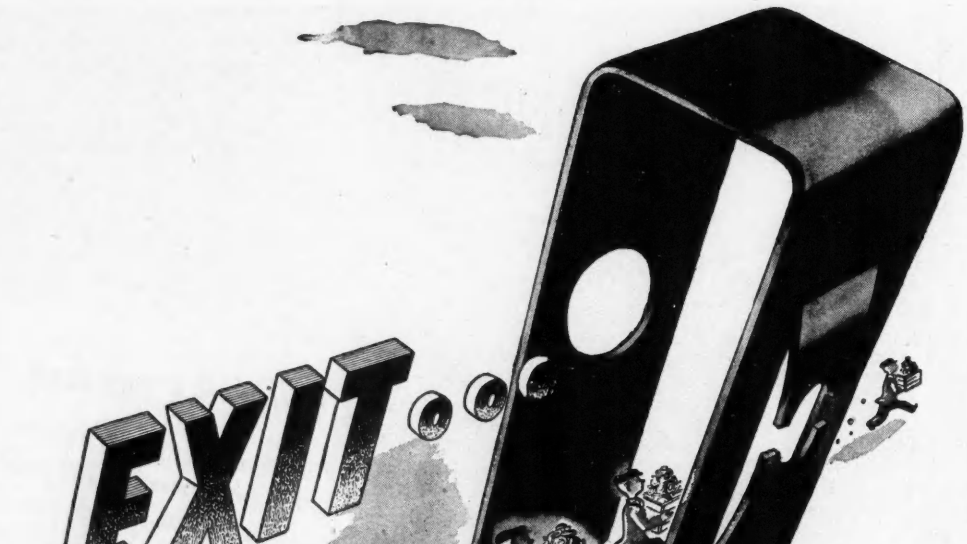


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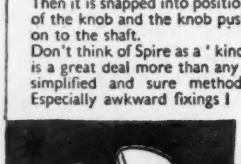

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one cycle of the drive signal) and may therefore be in error up to ± ½ unit. Greater errors than this are possible, even assuming perfect operation, since both the starting and stopping pulses may be received at any phase during one cycle of the oscillator. Analysis of these facts shows that with a perfect counter chronometer the maximum errors will be within ± 1 unit and the probable error ± ⅛ unit (*i.e.*, in a large number of operations a few might have errors approaching ± 1, but the errors would be less than ± ⅛ unit in about half the total number of operations). As this is the fundamental limit to the attainable accuracy it is desirable that any further errors introduced by the switching operation should be small compared with ⅛ unit. The time lag in the trigger circuits is negligible and the only possible source of appreciable error is the manner in which valve *50* comes into operation at the beginning of the time interval and goes out of operation at the end of the time interval. This involves the value of the bias, the ratio of the bias change to the oscillator amplitude and the ratio of the coupling time constant to the period of the oscillator. These have been adjusted so that the systematic error is small compared with ⅛ cycle. While the circuit values have been chosen primarily with the object of removing this error it may be observed that the resulting values are entirely favourable in other respects, *e.g.*, there is ample safety factor against the effects of variations in voltages and component values.

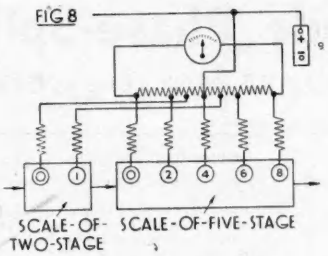
Two pre-set resistances, *6* and *29* in the circuit of Fig. 7, serve to adjust the threshold value of the starting and stopping grid voltage. The limits of voltage obtainable with adjustment of these resistances are 3-4½ volt peak to 7½-9 volt maximum peak.

### Indicating Meter Circuit

The use of normal current meters for indicating the state of the counter circuit and hence the actual count is made possible by the constancy of the operating current in each valve, due to the effect of resistances *15* and *42*. (Fig. 1).

The circuit arrangement adopted for this meter circuit is given by the Fig. 8. The complete circuit arrangement of Fig. 1* also shows this circuit.

Referring to Fig 8, the anode current to the valve passes through a tapped shunt across the meter. Each valve in turn takes the same operating




current, but the fraction of that current which passes through the meter depends on the tapping on the shunt from which the current is taken.

If these tapping points are made at equal resistance intervals, the successive operation of the valves will produce equidistant current steps through the meter, and instead of the scale being calibrated in current, it may in effect be marked to indicate directly which valve in the chain is operating.

The meter shown is of the centre-zero type, in which case the shunt is symmetrical and fed at the centre tapping. The resistance is so designed that the combined currents through valves 0 and 0 (corresponding to valves *10* and *34* in Fig. 1), are sufficient to deflect the pointer to the extreme left of the scale, which is then marked '0.'

When valve *1* (Fig. 8) becomes operative, the current to it flows through the tapping on the opposite side of the centre tap and the value is substracted instead of added to the current through valve 0 in the scale-of-five stage. The pointer therefore moves up the scale to a point marked '1.' For each combination of valves operating, similar points can be found.

A variable resistance (18 of Fig. 1) is provided in the circuit of each unit to adjust the absolute value of the current steps to suit the meter sensitivity.

One advantage of the centre-zero type of meter is in the reduction of error due to the pointer indications not being coincident with the scale markings. With a side zero meter these errors would be cumulative throughout the scale, but with the centre-zero type the maximum error on an individual reading is half the total cumulative error.

### Representative Complete Decimal Counter Chronometer

The photograph of Fig. 9 illustrates a typical chronometer employing 'scale of ten' units.

Careful attention has been given to the question of accuracy and reliability in its design and a number of detail features are incorporated to facilitate its use. These detail features are dealt with briefly since they do not constitute a real part of the design of the essential scale of ten unit.

The instrument comprises 5 scale of ten units, a switch unit, a crystal stabilised 100 kc/s. oscillator, a 5-dial indicating panel and the power supply for the foregoing units.

'Input start and stop' terminals are provided as well as manually operated 'start and stop' push buttons.

The switch unit has a 4-position switch fitted to permit switching to the internal 100 kc/s. drive or to external drive signals. In addition, one position of this switch permits a 100 c/s. drive (obtained from the 50 c/s. mains supply) to be applied to the counting circuits for testing purposes. Provision is made for the inclusion of a 1,000 c/s. fork-stabilised drive unit. This particular instrument has been manufactured in fairly large numbers and is in continuous service in many establishments concerned with the accurate measurement of time intervals.

In addition to its use for counting a finite number of impulses the circuit of Fig. 1 may obviously be used as a frequency divider since the operation of the circuit is repetitive for every *n* impulses applied. As a frequency divider the circuit has the advantage over most other forms of frequency divider that its operation is aperiodic and the ratio of division is not dependent on the value of the input frequency. Most other forms of frequency divider have a natural frequency and operate at the nearest submultiple above or below this natural frequency so that if the input frequency changes more than a certain amount the division ratio is liable to jump to another value. The operation of the circuit may also form the basis for any high speed step-by-step switch.

A modified version of this instrument has also been supplied which is arranged to provide time intervals, *i.e.*, it is a Time Interval Generator having a high order of accuracy.

The applications of the chronometer are very numerous and the convenient indicating system in the scale of ten system of numbers commends it to the majority of users in preference to the 'scale of two' instrument.

In conclusion, the author gratefully acknowledges the assistance given by Mr. T. C. Nuttall who was responsible for the circuit design.

* See last month's issue

# The Twin Triode Phase-Splitting Amplifier

By J. D. CLARE, M.Sc.,(Eng.)., Grad.I.E.E.*

THE twin triode phase splitting amplifier is now quite a well known device.[1, 2, 3]

This article suggests a practical modification of the circuit which can be used to operate the twin triodes under optimum conditions with a minimum number of components and to give a flat "gain-frequency" response over a very wide audio band.

An analysis of the circuit gives:—

(a) The value of the two anode loads for a balanced push-pull output.

(b) The amplification of the circuit.

(c) The change in amplitude balance of the two out-of-phase output voltages for a given percentage change in the valve parameters, assuming all the other circuit components are fixed in value.

**SYMBOLS USED**

| | |
|---|---|
| $R_k$ | Common cathode resistor |
| $E_i$ | Input voltage |
| $e_{o1}$ | Output voltage of valve $V_1$ |
| $e_{o2}$ | Output voltage of valve $V_2$ |
| $e_k$ | A.C. voltage developed across $R_k$ |
| $R_1$ | Anode load of valve $V_1$ |
| $R_2$ | Anode load of valve $V_2$ |
| $R_{a_1}$ | Internal impedance of valve $V_1$ |
| $R_{a_2}$ | Internal impedance of valve $V_2$ |
| $g_1$ | Mutual conductance of $V_1$ |
| $g_2$ | Mutual conductance of $V_2$ |
| $g_1'$ | Effective mutual conductance of $V_1$ $\frac{g_1.R_{a_1}}{R_{a_1}.R_1}$ |
| $g_2'$ | Effective mutual conductance of $V_2$ $\frac{g_2.R_{a_2}}{R_{a_2}.R_2}$ |
| $\mu_1$ | $g_1R_{a_1}$ |
| $\mu_2$ | $g_2R_{a_2}$ |
| $I_1$ | a.c. component of anode current of $V_1$ |
| $I_2$ | a.c. component of anode current of $V_2$ |

### Value of the Anode Loads for Balanced Output

The basic circuit under consideration is shown in Fig. 1.

Then we have:

$$I_1 = g_1'(E_1 - e_k) \quad \ldots\ldots (1)$$

$$I_2 = -g_2'e_k \quad \ldots\ldots (2)$$

$$e_k = (I_1 + I_2)R_k \quad \ldots\ldots (3)$$

Equations (2) and (3) give

$$e_k = \frac{I_1R_k}{1 + g_2'R_k}$$

Substituting for $e_k$ in Equation (1) gives:

$$I_1 = g_1'\left(E_1 - \frac{I_1R_k}{1 + g_2'R_k}\right)$$

$$\text{or } I_1 = g_1'E_1 \frac{1 + g_2'R_k}{1 + R_k(g_1' + g_2')} \quad \ldots (4)$$

Equations (1) and (3) give:

$$e_k = R_k[g_1'(E_1 - e_k) + I_2]$$

$$e_k = \frac{R_kI_2 + g_1'E_1R_k}{1 + g_1'R_k}$$

Substituting for $e_k$ in Equation (2) gives:

$$I_2 = \frac{-g_2'(R_kI_2 + g_1'E_1R_k)}{1 + g_1'R_k}$$

$$I_2 = \frac{-g_1'E_1g_2'R_k}{1 + R_k(g_1' + g_2')} \quad \ldots\ldots (5)$$

$$e_{o1} = -I_1R_1$$

$$= -g_1'E_1R_1\frac{(1 + g_2'R_k)}{1 + R_k(g_1' + g_2')} \quad \ldots\ldots (6)$$

and $e_{o2} = -I_2R_2$

$$= g_1'E_1R_2\frac{(g_2'R_k)}{1 + R_k(g_1' + g_2')} \quad \ldots\ldots (7)$$

Therefore:

$$\frac{e_{o1}}{e_{o2}} = \frac{-(1 + g_2'R_k)R_1}{g_2'R_k.R_2} \quad \ldots\ldots (8)$$

Two output voltages are required to be equal in magnitude for a push-pull drive.

When $e_{o1} = -e_{o2}$ a balanced push-pull output is therefore obtained, *i.e.*, from Equation (8)

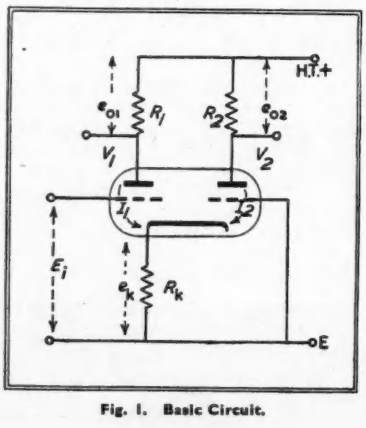



Fig. 1. Basic Circuit.

when $\frac{R_2}{R_1} = \frac{1 + g_2'R_k}{g_2'R_k}$

and $\frac{1 + g_2'R_k}{g_2'R_k} = 1 + \frac{1}{g_2'R_k}$

$$= 1 + \frac{R_{a2} + R_2}{g_2R_{a2}R_k} = 1 + \frac{R_{a2} + R_2}{\mu_2R_k}$$

Hence, for a balanced push-pull output:

$$\frac{R_2}{R_1} = 1 + \frac{1}{g_2'R_k} = 1 + \frac{R_{a2} + R_2}{\mu_2R_k} \quad \ldots. (9)$$

This implies that the values of $\mu_2$ and $R_{a2}$ for the second valve $V_2$ need only be considered.

### Amplification of the System

Assuming the two output voltages are equal, then:

$$\text{Amplification} = e_{o1}/E_1 = -e_{o2}/E_1$$

Therefore, from Equation (6) we get:

$$\frac{e_{o1}}{E_1} = \frac{-g_1'R_1(1 + g_2'R_k)}{1 + R_k(g_1' + g_2')}$$

If $g_1'R_k$ and $g_2'R_k$ are both much greater than unity, then:

$$\frac{e_{o1}}{E_1} \approx \frac{-g_1'R_1g_2'R_k}{R_k(g_1' + g_2')} = \frac{-R_1g_1'g_2'}{g_1' + g_2'}$$

If $R_1 \approx R_2$ and $g_1' \approx g_2'$, which is normally the case, then

$$\frac{e_{o1}}{E_1} \approx \frac{-g_1'R_1}{2} \quad \ldots\ldots (10)$$

That is, the amplification is half that normally obtained from the valve with an anode load of $R_1$.

With the availability of such valves as the 6SN7, providing two triodes in one envelope, the circuit has advantages for inclusion not only in quality amplifiers but also in commercial radio sets where a push-pull output is employed.

In this connexion, all the circuit component values will be pre-determined and it is necessary to know how the amplitude balance of the two output voltages will vary with the variation of valve parameters within the normal production limits.

It can be seen from Equation (8) that the ratio $e_{o1}/e_{o2}$, assuming that $R_1$ and $R_2$ are fixed, is completely independent of $g_1'$ and only dependent on $g_2'$.

* Research Department, R. F. Equipment Limited, Amersham.

This means that changes in the characteristics of the valve $V_1$ will in no way affect the amplitude balance of the two output voltages $e_{01}$ and $e_{02}$.

#### Constancy of Amplitude Balance of the Push-pull Output

Assuming that $R_1$ and $R_2$ are fixed in ratio as given by Equation (9), and taking $R_{a2}$ and $\mu_2$ as the average values given by the manufacturer, what will be the change in amplitude balance of $e_{01}$ and $e_{02}$ for the normal production variations in characteristic of the valve $V_2$?

The overall effective amplification of a triode in a given circuit should stay within ± 10 per cent. for different valves of the same type. This, applied to the valve $V_2$ means that $g_2'$ can vary within the limits of ± 10 per cent.

Assuming a change of $k$ per cent. in $g_2'$, what will be the change in the ratio $e_{01}/e_{02}$?

$g_2'$ changes by $k$ per cent. to $g_2'\left(1 + \frac{k}{100}\right)$ and $e_{01}'$ – $e_{02}$ changes from

$$\frac{(1 + g_2'R_k)R_1}{g_2'R_kR_2} \text{ to } \frac{[1 + g_2'(1 + (k/100))R_k]R_1}{g_2'(1 + (k/100))R_kR_2}$$

The percentage change in $e_{01}/e_{c2}$ is therefore

$$100\left[\frac{(1 + g_2'R_k)R_1}{g_2'R_kR_2} - \frac{[1 + g_2'(1 + (k/100)R_k]R_1}{g_2'(1 + (k/100))R_kR_2}\right]$$

or $$\frac{100k}{100 + k} \cdot \frac{R_1}{R_2g_2'R_k}$$

From Equation (8) $\frac{1}{g_2'R_k} = \frac{R_2 - R_1}{R_1}$

The percentage change in $e_{01}/e_{02}$ is therefore:

$$\frac{100k}{100 + k} \cdot \frac{R_2 - R_1}{R_2} = \frac{100k}{100 + k} \cdot \frac{1}{1 + g_2'R_k} \quad \ldots\ldots\ldots\ldots (11)$$

#### Suggested Practical Circuit

In Fig. 2, where a preceding amplifier is available as, for example, the usual double-diode-triode in a radio receiver, the anode voltage of the triode ($E_X$) can be utilised to enable a large D.C. voltage to appear across $R_k$ and hence to make $R_k$ and $g_2'R_k$ large.

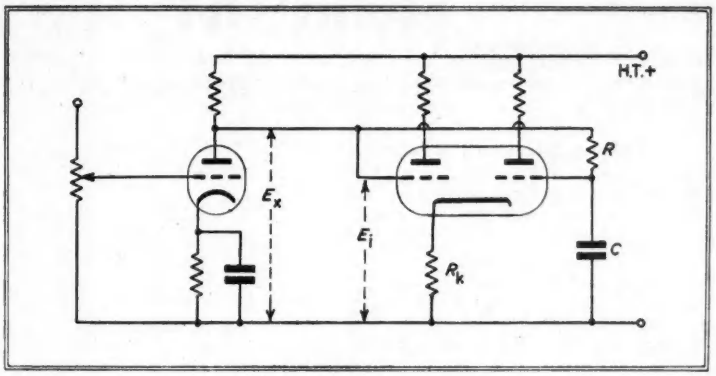



Fig. 2. Suggested practical circuit.

Let us now consider a practical case using a 6SN7 as a twin triode.

$R$ = 1.0 megohm.
$C$ = 0.25 μF.
$\mu$ = 20 for each valve..
$R_a$ = 10,000 ohms for each valve at the operating point chosen ($I_a$ 2.5 mA, $E_a$ 110 V).
H.T. voltage = 300.
D.C. anode current 2.5 mA per valve.
$E_X$ = 100 volts.
$R_k$ = 25,000 ohms.

It can be seen from Table 1 that it is possible to obtain from this circuit arrangement a 25 + 25 r.m.s. voltage output for a push-pull drive, without overloading.

#### Amplitude Balance of Output Voltages

From Equation (11) a 10 per cent. change in $g_2'$, *i.e.*, a 10 per cent. change in the effective gain of $V_2$, gives a change in the balance of $X$ per cent. where $X = \frac{1,000}{110} \cdot \frac{2.9}{35} = 0.75$ per cent. in $e_{01}/e_{02}$.

TABLE I

| Ei volts | e01 volts | e02 volts | Average Amplification for each valve |
|---|---|---|---|
| .84 | 6.75 | 6.87 | 8.0 |
| 1.65 | 12.5 | 12.45 | 7.7 |
| 2.35 | 18.5 | 18.5 | 7.9 |
| 3.1 | 24.5 | 24.6 | 7.95 |
| 3.5 | 27.75 | 27.2 | |
| 3.75 | 31. | 28.2 | |

$$g_2'R_k = \frac{\mu_2R_k}{R_{a2} + R_2} = \frac{20 \times 25}{10 + 35} = 11 \text{ approx.}$$

If $R_2$ = 35,000 ohm and $R_1$ = 32,100 ohm, *i.e.*, if

$$\frac{R_2}{R_1} = \frac{35}{32.1} = \frac{1 + g_2'R_k}{g_2'R_k} = \frac{12}{11}$$

The theoretical gain is approximately:

$$\frac{g_2'R_2}{2} \approx \frac{g_2'R_1}{2} = \frac{11 \times 35}{25 \times 2} = 7.7.$$

The values of $e_{01}$ and $e_{02}$ for various input voltages at a frequency of 400 c/s. are shown in Table 1.

This means that it is possible to use such a circuit with pre-determined values of $R_1$ and $R_2$. Even allowing for production variations of $g_2'$, the amplitude balance of the push-pull drive will be within ± 1 per cent., and, what is more, constant with varying frequency.

#### Frequency Response

The only factor which can affect the frequency response over a very wide audio band is the decoupling network $R$-$C$ at the lower frequencies.

With $R$ made as high as 1 – 2 megohms, it is easy to make $C$ large enough for adequate decoupling at the lowest audio frequency. The values for $C$ and $R$ as given for the circuit arrangement shown in Fig. 2 are adequate to give a flat frequency response from 50 c/s. to 15 kc/s.

Over this range the amplifier was completely flat within the limits of the measuring equipment. This was of the order of ± 0.1 db.

#### Application to Cathode-coupled Output Stage

If the anode load resistors are replaced by the two balanced windings of a push-pull transformer in a cathode-coupled output stage[3], then the same considerations with regard to the push-pull balance will apply.

### REFERENCES

[1] O. H. Schmitt. *Journal of Scientific Instruments*. March 1938, Vol. 15. p.100.
[2] W. T. Cocking. *Wireless World*, 13th April 1939. Vol. 44. p. 343 344.
[3] S. W. Amos, *Wireless Engineer*, Feb. 1946. Vol. 23. p.43–46.

# FEBRUARY MEETINGS

*NOTE.— In general, visitors are admitted to the meetings of scientific bodies on the invitation of a member, or on application in writing to the Organising Secretary at the address given. In certain cases (marked *) tickets may also be obtained on application to the Editorial offices of this Journal.*

### Institution of Electrical Engineers

All meetings of the London Section will be held at The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.

#### Radio Section

Date: February 5. Time: 5.30 p.m.
Lecture: "The Calculation of Field Strengths over a Spherical Earth."
By: C. Domb, M.A. and M. H. L. Pryce, M.A., Ph.D.

Date: February 19. Time: 5.30 p.m.
Lecture: "The Design of High-Fidelity Disk-Recording Equipment."
By: H. Davies, M.Eng.

Date: February 25. Time 5.30 p.m.
Lecture: "The Economics of Transmitting Station Design."
By: B. N. MacLarty, O.B.E.

#### Measurements Section

Date: February 7. Time: 5.30 p.m.
Discussion on: "What has the Electrical Instrument Industry to learn from developments in Continental Practice?"
Opened by: F. E. J. Ockenden and G. N. Harding.

#### Informal Meeting

Date: February 24. Time: 5.30 p.m.
Discussion on: "Hot-Cathode and Cold-Cathode Discharge-Tube Lighting."
Opened by: Prof. H. M. Barlow, Ph.D., B.Sc.(Eng.).
*The Secretary: I. E. E., Savoy Place, London, W.C.2.*

#### London Students Section

Date: February 18. Time: 7 p.m.
Discussion: "Radio Modulation Methods —Amplitude, Phase, Frequency and Pulse."
Opened by: G. Dawson, D. Deacon, and R. F. Howard.
*Secretary: I.E.E., Savoy Place, London, W.C.2.*

#### Cambridge and District Group

Date: February 25. Time: 6.30 p.m.
Held at: The Cavendish Laboratory, Cambridge.
Lecture: "The Use of Electronics in Nuclear Physics."
By: E. S. Shire, M.A.
*Secretary: D. H. Hughes, c/o Pye Ltd., Radio Works, Cambridge.*

#### North-Eastern Radio and Measurements Group

Date: February 3. Time: 6.15 p.m.
Held at: King's College, Newcastle-on-Tyne.
Lecture: "A Method of Transmitting Sound in the Vision Carrier of a Television System."
By: D. I. Lawson, M.Sc.,; A. V. Lord, B.Sc.Tech., and S. R. Kharbanda.
*Secretary: G. A. Kysh, c/o N.E.S. Co. Ltd., Carliol House, Newcastle-on-Tyne, 1.*

#### Tees-Side Sub-Centre

Date: February 5. Time: 6 p.m.
Held at: The Cleveland Scientific and Technical Institute.
Lecture: "Industrial Applications of Electronic Techniques,"
By: H. A. Thomas, D.Sc.
*Secretary: J. C. B. Nicol, 45, Lothian Road, Middlesbrough.*

#### North Midland Centre

Date: February 11. Time: 6 p.m.
Held at: The Leeds Corporation Electricity Department, Whitehall Road.
Lecture: "A Survey of the Development of Radar."
By: R. A. Smith, M.A., Ph.D.
*Secretary: H. S. Moody, The Yorkshire Power Co., Manor Farm, Bramhope, Leeds.*

#### North-Western Radio Group

Date: February 27. Time: 6 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: "The Pulse Testing of Wide-Band Networks."
By: D. C. Espley, D.Eng.,; E. C. Cherry, M.Sc., and M. M. Levy.
*Secretary: G. I. Thomas, 63, St. Johnston Street, Tyldesley, Nr. Manchester.*

### The Television Society*

Date: February 12. Time: 7.15 p.m.
Note: This is a joint meeting with the British Kinematograph Society. *q.v.*
*Secretary: G. Parr, 68, Compton Road, Winchmore Hill, London, N.21.*

### The British Kinematograph Society*

Date: February 12. Time: 7.15 p.m.
Held at: Film House, Wardour Street, London, W.1.
Lecture: "The Film in Relation to Television."
By: M. F. Cooper.
*Secretary: R. H. Cricks, Dean House, Dean Street, W.1.*

### Society of Instrument Technology

Date: February 25. Time: 7 p.m.
Held at: Royal Society of Tropical Medicine and Hygiene, Manson House, Portland Place, London, W.1.
Lecture: "The Reliability of Small Electrical Apparatus."
By: A. C. Lynch, M.A.
*Secretary: L. B. Lambert, 55, Tudor Gardens, London, W.3.*

### The British Sound Recording Association

Date: February 28. Time: 7 p.m.
Held at: The Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2.
Lecture: "Problems of Sound Reproduction."
By: L. E. C. Hughes, Ph.D., A.M.I.E.E.
*Secretary: R. W. Lowden, 3a, Pembroke Buildings, Camberley, Surrey.*

### The Institute of Physics

#### Scottish Branch

Date: February 18. Time: 7 p.m.
Held at: The University, Glasgow.
Lecture: "Dielectric Heating,"
By: A. J. Maddock, F.Inst.P., M.I.E.E.
*Secretary: W. G. Marskell, Messrs. Babcock and Wilcox Ltd., Renfrew.*

#### Industrial Radiology Group

Date: February 21. Time: 6.30 p.m.
Held at: Royal Society, Burlington House, Piccadilly, W.1.
Lecture: "The Organisation of Aircraft Radiology During the War."
By: W. L. Harper, B.Sc.
*Secretary: Dr. L. Mullins, Research Laboratories, Kodak Ltd., Harrow, Middlesex.*

### Brit. I.R.E.

#### London Section

Date: February 20. Time: 6 p.m.
Held at: The London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.
Lecture: "A.C. Behaviour of the Barrier-Layer Photo--cell."
By: J. A. Sargrove.
*Secretary: The British Institution of Radio Engineers, 9, Bedford Square, W.C.1.*

#### North-Eastern Section

Date: February 12. Time 6 p.m.
Held at: Neville Hall, The North of England Institute of Mining and Mechanical Engineers, Westgate Road, Newcastle-on-Tyne.
Lecture: "Deaf Aid Systems."
By: Dr. R. T. Craig.
*Secretary: G. C. Turner, 2, Coleridge Road, Manchester, 16.*

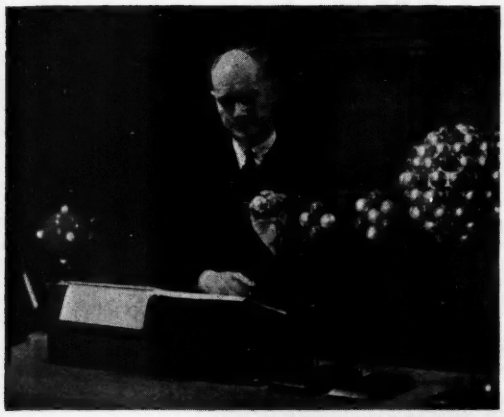
#### Scottish Section

Date: February 13. Time: 6.45 p.m.
Held at: The Institution of Engineers and Shipbuilders in Scotland, Elmbank Crescent, Glasgow, C.2.
Lecture: "Electronics in Nuclear Research."
By: J. M. A. Lenihan, M.Sc.
*Secretary: H. G. Henderson, Muirburn Avenue, Muirend, Glasgow, C.4.*

### Ilford and District Radio Society

All meetings are held at St. Albans Church Room, Albert Road, Ilford.
Date: February 6. Time: 8 p.m.
Lecture: "A Home Made Oscilloscope." (With demonstration).
By: H. Chinnery.
Date: February 13. Time: 8 p.m.
Members' Meters, with short talks on same.
Date: February 20. Time: 8 p.m.
Lecture: "Timekeeping from Earliest Days to First Mechanical Stage." (This is the first of four monthly lectures to embrace progress up to Quartz and Electric Clocks).
By: H. T. Stott, M.B.H.I.
*Secretary: C. E. Largen, 44, Trelawney Road, Barkingside, Ilford, Essex.*

# TELEVISION COMMENTARY



**Dr. Allibone giving his Faraday lecture on Atomic Energy before the television camera, Dec. 7th, 1946. (Right). Stage setting for "Morning Departure," the action of which takes place in a submarine. The crew on the left are "off-stage" at the moment. Jan. 1st, 1947.**

*—Photos by courtesy of the B.B.C.*

NOW that the Christmas tide has ebbed, the reactions of some of the very youngest viewers to their own programmes may be worth noticing. Children were so very generously catered for during the holidays that it is possible to mention only a few of the programmes. Three held a rapt attention from beginning to end and were afterwards discussed often and enthusiastically.

"Toad of Toad Hall" (December 29 and January 6), Bertram Mills Circus from Olympia (December 26 and 27), and "Just William" televised from the stage performance at the Granville Theatre, Walham Green (December 23) were the three winners.

"Toad of Toad Hall" was an outstanding success and adult viewers found it one of the most exquisite studio productions that has yet come from Alexandra Palace. The Circus pictures from Olympia were excellent in spite of the necessary absence of special television lighting, and only the high trapeze act made an inferior picture because the cameras were compelled to face the brilliant top light.

"Alice in Wonderland" (December 21 and 24) was a technical tour de force. Alice actually diminished before our eyes by clever manipulation of super-posed images from two separate cameras. In a similar mysterious manner, the Cheshire cat and its grin appeared and disappeared, separately and together, from above the mantelpiece. In spite of a charmingly cast Alice, and this delightful juggling with cameras, "Alice in Wonderland" was turned down by the young. Its pace was a little too deliberate to catch the real fantasy.

Pantomime was courageously attempted but it is, by television, inevitably a pale ghost of the robust, colourful reality, and perhaps it is one of the things which should wait for colour television. At any rate, the studio performance of "Cinderella" (January 2 and 3) was soon switched off, though no doubt this would come into its own when it can reach remoter areas where real pantomime is not accessible.

These and many other excellent juvenile programmes have proved both to the children and their parents that television can do more than hold its own against the attractions of the cinema.

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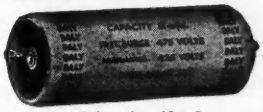

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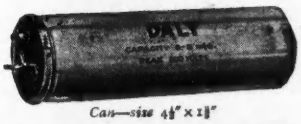

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# BOOK REVIEWS

## A Handbook of Telecommunication

**Telephony and Telegraphy over wires) B. S. Cohen, O.B.E., M.I.E.E., F.Inst.P. Pitman 30s., 409 pages and Index.**

The author of this book, who was for some years Director of the Post Office Research Station, sets out to achieve a most ambitious object—to state the principles underlying the whole of the telecommunication field. In this he has been successful to a degree which is remarkable considering the restrictions of space imposed by the length of the book. There is, in fact, little in the communication art that is not dealt with in one form or another, the volume giving a good cross-section of the fundamentals of all branches of telecommunication as practised in the period 1940-42.

The scope includes manual and automatic exchange equipment, basic circuits and trunking, junction and trunk working, a brief reference to the major overseas systems, transmission line theory and calculations, amplifier and echo suppressor design, filters, multichannel working, external plant, valve characteristics, telegraphy and testing methods.

A particularly useful feature is the long and comprehensive list of references to specialised literature at the end of each chapter. These are excellently chosen and apt expansions of the necessarily condensed and at times abbreviated information with which they are associated, and enable the reader interested in any particular aspect of telecommunication to pursue the matter further than would be possible from the book itself. There are, for example, no less than 35 references for the section dealing with external plant alone.

One feature of the book appears to be open to criticism; that is, that the degree of detail given in the sections devoted to the various aspects of telecommunication varies widely. Thus, although a considerable amount of tabulated information and formulæ are given in connexion with the transmission characteristics of lines, automatic telephony is dealt with almost entirely by means of trunking diagrams, and trunking calculations and the traffic carrying capacity of junctions are hardly mentioned. Again, valve apparatus of the types used in transmission channels are described in detail, but the characteristics of relays, of which many more are used in communications than valves, are limited to one or two pages.

In spite of these limitations, many of which are no doubt dictated by considerations of space, the book does give a very readable account of the wide field it purports to cover, and will be of considerable interest not only to the specialist in one of the many aspects of telecommunications who wishes to learn something of the other phases of the art on the fringes of his own, but also to electrical engineers generally, most of whom at one time or another have to know something of milliampere technique. The book is also likely to be of use to the student in the early stages of learning, though the advanced pupil will need to expand his reading to include the references to specialised subjects.

A. A. CHUBB.

## Wave Propagation in Periodic Structures

**by Léon Brillouin (McGraw-Hill. 247 pages. Price 20s.)**

Those with a taste for mathematical physics will recall the pleasure of their first appreciation of the fact that the same mathematical language may serve to describe a diversity of physical phenomena. They would have noted, for instance, that the mathematics of wave propagation in continuous media could be applied to media with widely different physical properties and that potential theory and vector algebra were of service in the study of hydrodynamics and electromagnetism alike.

It is in this spirit of " plus ça change, plus c'est la meme chose " that Professor Léon Brillouin has written " Wave Propagation in Periodic Structures," as the following quotation from the Preface illustrates—" When Lord Kelvin built up his model for a dispersive medium or when Lord Rayleigh discovered radiation pressure, they never failed to try the same methods again and again on all conceivable types of waves. This general philosophy of wave propagation, forgotten for a time, has been strongly revived in the last decade and represents the backbone of this book."

Although the book is concerned with the common mathematical background to the study of wave propagation in periodic structures of various well-known types such as the simple one-dimensional lattice of point masses, two and three dimensional crystal lattices and electrical wave filters, yet it is certain that such a masterly and original survey of the subject could only have been written by an author such as Professor Brillouin, who is himself an original contributor of distinction to many branches of mathematical physics.

The book begins with an introductory chapter containing an historical survey of the subject from the first investigation by Newton on a one-dimensional lattice to Born's work on the NaCl crystal. This survey stresses the importance of Kelvin's researches which anticipated much subsequent work, and his complete grasp of the essentials of the problem of wave propagation in one-dimensional lattices. The analogy between electric filters and one dimensional lattices is also noted.

Chapters II to V, inclusive, comprise a detailed treatment of wave propagation in one-dimensional lattices, including lattices of mass points, crystal lattices and electric wave filters. The discussion in Chapter V of energy flow and characteristic impedance in one-dimensional lattices should be of interest to electrical engineers. The author concludes the chapter thus, "The characteristic or surge impedance, familiar to electrical engineers, is very useful for one-dimensional structures with interactions between nearest neighbours only. This includes practically all problems of filters, lines and cables for electrical communications. We have found how delicate is the extension to dimensional structures with interactions at large distances. Despite many interesting attempts, the extension to two or three dimensions remains rather artificial."

Chapters VI and VII deal respectively with two- and three-dimensional lattices and the subject matter is so arranged that the reader passes smoothly from the less difficult to the more difficult concepts without finding it necessary to seek information from other sources.

The remaining chapters contain valuable discussions of Mathieu's and Hill's equations the self-excited oscillator, electrons in metals and the application of matrix algebra to the study of wave propagation in the electric lines.

Two final quotations will perhaps serve best to enable the reader to assess the spirit and value of this book. On page 193 we read, " Hence for scientists of the last century, it was common knowledge that the special nature of the waves did not matter and that the same general principles could be found for any type of waves. The general relations among the various types of waves seem to have been forgotten for some time. Physicists developed the theory of electromagnetic waves for optics and X-rays. Then theoreticians discussed very carefully the properties of electron waves (wave mechanics) in crystals and too often did not pay attention to the fact that a great part of the work had already been done in the theory of X-ray propagation in crystals.

On the other hand, electrical engineers did a wonderful analysis on the theory of propagation of waves along lines, cables, filters, etc., but omitted to notice that many important facts had already been discovered by theoretical physicists."

Again, on page 194, " Recent developments in wave mechanics point to the importance of matrix calculus and its

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very close connexion with a number of problems of wave propagation. It is very interesting to note that electrical engineers have independently come to the same conclusion.

Matrix theory is now commonly used in the discussion of problems of waves in electric filters. Furthermore, these problems seem to represent the only classical example where some special matrices, of great importance for the theory of electron spin, appear for practical purposes, and we shall try in the next chapter to show the connexion between the theory of electric filters and the Pauli-Dirac wave theory of the spinning electron."

This book provides, in effect, a body of cogent argument against the departmentalisation of knowledge in the physical sciences and, as such, is to be recommended to engineers and physicists alike.

L. G. H. HUXLEY.

## Reference Data for Radio Engineers

**by W. L. McPherson (Standard Cables and Telephones, Ltd. Connaught House, Aldwych, W.C.2. 5s. net, post free 5s. 6d.)**

This is a second edition of a useful reference book which was originally compiled for the use of Standard Telephones' engineering staff and which has been issued to a wider public. The opportunity has been taken to incorporate much additional material, and the book now contains 172 pages of data and tabular information.

In addition to general engineering tables, there are sections on audio and radio design, valves and rectifiers, r.f. transmission lines, radio propagation and noise measurement. Mathematical formulæ and tables add to the value of this reference book which is published at a very reasonable price.

## Marconi 1939 — 1945

**by George Godwin. (Chatto & Windus, 1946. 10s. 6d. net. 125 pp. 79 photographs).**

This book is a war record of Marconi's Wireless Telegraph Company Limited, intended primarily for the non-technical reader.

In simple language it outlines the many activities of the company and gives a good idea of the very great number of uses to which radio communication and radar were put during the recent war.

The main feature of the book is the photographs which are liberally distributed among its pages. It is, in fact, largely a pictorial book and the pictures are of a very high standard of technical and pictorial excellence.

As a record of the company's war activities the book is disappointing to one who might expect a few technical matters to be dealt with, but if this is not expected, the book will not fail to interest if for the illustrations alone.

R.M.W.

## An Electronic Beetle Tracer

RECENTLY a new form of Geiger-Müller tube has been developed (by G.A.R.T.) which has been found extremely useful in studying the movements of Elaterid beetles of the genus *Agriotes* Esch. As these beetles are known to fly but rarely in Britain, a study of the extent to which they may move by walking is of considerable interest.

A beetle is taken from the field, and 5 μgm. of radium sulphate, deposited between aluminium foil disks (2 mm. in diameter and weighing in all only 0.5 mgm.), are inserted with resin adhesive beneath the elytra. The beetle is replaced, and its position afterwards found by detecting the radiation from the disk with a Geiger-Müller tube. The tube, which has the advantage of quiet background, stable operation, and a high sensitivity,, together with its associated power supply, operates a loudspeaker directly, without any valve amplification, and is thus very convenient for field use. When it is passed over the region in which the beetle is thought to lie, periodic ticks increase in frequency to a maximum when the tube is directly overhead. The quantity of radium sulphate used is sufficient to enable localisation through 4 in. of soil, and the beetle's position may thus be ascertained to within a few inches with only the preliminary interference of marking, although it is quite invisible, either at night, or by day under soil, or among the dense stem bases of meadow plants.

It is probable that this robust apparatus will find many applications in ecological field work in the future.

G. A. R. TOMES,
20th Century Electronics,
London.

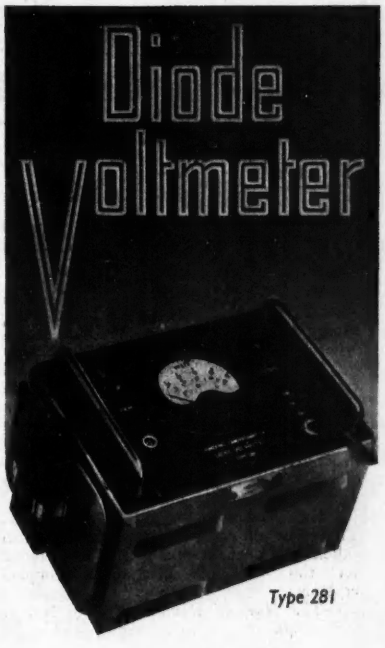
M. V. BRIAN,
Rothamstead Experimental Station,
Harpenden, Herts.

—From "*Nature*," Oct. 25, 1946.

## New Acoustics Group of the Physical Society

A meeting of all interested in the formation of an acoustical group will be held in the Jarvis Hall of the Royal Institute of British Architects, 66 Portland Place, W.1, at 3 p.m., on Wednesday, February 19, 1947.

All interested persons should write to the acting secretaries, Mr. A. T. Pickles and Mr. W. A. Allen, 1 Lowther Gardens, London, S.W.7.

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# ABSTRACTS OF ELECTRONIC LITERATURE

## THEORY

### Generalised Curves for the Design of the Two-Crystal Bandpass Filter

*(J. D. Brailsford)*

This paper submits a method which is comparable in simplicity to that commonly employed for coupled circuit filters where use is made of generalised curves.

The new design curves give the actual transmission loss of the filter when used as an intervalve coupling. It may happen that the Q of the coils incorporated with the crystals in the network is limited by practical rather than by ideal considerations. The curves, however, will still indicate the correct use of such coils and the variation in response that will follow. The effect of crystal mismatching is also taken into account and a note is included on the use of mechanically-coupled crystals.

—*The Marconi Review*, Vol. 9, No. 2, p. 40.

### Theory of Communication

*(D Gabor)*

The purpose of these three studies is an inquiry into the essence of the "information" conveyed by channels of communication and the application of the results of this inquiry to the practical problem of optimum utilisation of frequency bands.

In Part 1, a new method of analysis signals is presented in which time and frequency play symmetrical parts, and which contains "time analysis" and "frequency analysis" as special cases. It is shown that the information conveyed by a frequency band in a given time-interval can be analysed in various ways into the same number of elementary "quanta of information," each quantum conveying one numerical datum.

In Part 2, this method is applied to the analysis of hearing sensations. It is shown on the basis of existing experimental material that in the band between 60 and 1,000 c/s the human ear can discriminate very nearly every second datum of information, and that this efficiency of nearly 50 per cent. is independent of the duration of the signals in a remarkably wide interval. This fact, which cannot be explained by any mechanism in the inner ear, suggests new phenomenon in nerve conduction. At frequencies above 1,000 c/s the efficiency of discrimination falls off sharply, proving that sound reproductions which are far from faithful may be perceived by the ear as perfect, and that "condensed" methods of transmission and reproduction with improved waveband economy are possible in principle.

In Part 3, suggestions are discussed for compressed transmission and reproduction of speech or music, and the first experimental results obtained with one of these methods are described.

—*Jour. I.E.E.*, Pt. 3. November, 1946, p. 429.

### Amplifier-Gain Formulas and Measurements

*(S. J. Haefner)*

This paper gives precise mathematical statement to the most widely accepted definitions and applies them in sample cases to make their full meaning evident and assure that they may be understood correctly. In addition, it develops and illustrates the application of a practical method for expressing the insertion gain of amplifiers used primarily for voltage amplification.

—*Proc. I.R.E.*, July, 1946, p. 500.

## RADIO

### Tuning Devices for Broadcasting Radio Receivers

*(R. C. G. Williams)*

The wide choice of entertainment provided by the broadcast receiver is perhaps its most important feature, and the development of tuning devices to simplify the exercise of that choice has played an important part in radio receiver design. Both station selection and ready identification of a programme found by random searching are involved. The paper opens with a brief historical review of tuning-device evolution from the introduction of a single-knob tuning to the immediate pre-war designs. Listening tests are used to establish the degree of mistuning to design tolerance for tuning errors. A consideration of frequency stability on the broadcast bands leads to an analysis of design limitations and establishes pre-set tuning on medium and long waves and band-spread tuning on short waves as important problems. The design of pre-set tuning devices is reviewed, together with their power drive and remote control, and the associated receiver circuits. Appendices give the measured frequency response and harmonic-content characteristics of the receiver used in the listening tests, together with a mathematical analysis of these characteristics as derived from the intermediate-frequency response.

—*Jour. I.E.E.*, Pt. 3. November, 1946, p. 405.

## INDUSTRY

### Improved Methods of Illuminating Instrument Dials

*(H. Huxley)*

The uniform illumination of instrument dials by methods involving the leading of light in plastics is discussed. Two main methods are considered: (1) the illumination of scales and pointers using a plastic ring surrounding the dials, and (2) the engraving of the scales on to plastic plates illuminated by light filling the plates. Selected examples with constructional details are given.

The methods recommended are intended to apply to instruments requiring accurate reading when used under critical conditions and were originally designed to meet the special demands of Service instruments, in particular the new requirement for red-light illumination.

—*Jour. Sci. Inst.*, October, 1946, p. 234.

### Electrolysis Phenomena in Soft-Glass Stems of Rectifier Tubes

*(J. Gallup)*

A study was made of the cause of stem cracks which developed along leads during the life of rectifier tubes. These were found to be due to electrolysis occurring in the soft-glass stems. The potential which produces the rupture was the result of glass bombardment by reverse emission from the rectifier plates. Other attendant electrolysis phenomena are described in the order in which they occurred.

A special double-ended tube was employed to study the gas produced in the electrolysis process. An analysis of the gas by means of the mass spectrometer gave composition results agreeing with those expected from electrolytic decomposition of soft glass.

—*Jour. Am. Ceramic Society*, October, 1946.*

### The Design and Application of Modern Permanent Magnets

*(A. J. Tyrrell)*

The development of the modern anisotropic permanent magnet alloy has greatly facilitated the application of permanent magnets to electrical apparatus which previously would operate efficiently only with energised magnets.

Modern permanent magnets frequently permit the design of smaller, lighter and cooler apparatus, with reduced power consumption. Accordingly, a relatively neglected branch of science has now acquired considerable importance from the engineering as well as the economic aspect.

The paper surveys the engineering application of permanent magnets with particular reference to the use of "Ticonal G" alloy.

—*Jour. Brit. I.R.E.*, September-November, 1946, p. 178.

* Abstracts supplied by the courtesy of Metropolitan-Vickers Electrical Co. Ltd. Trafford Park, Manchester

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# NOTES FROM THE INDUSTRY

### Sir Robert Watson-Watt

The Ministry of Supply announces that Sir Robert Watson-Watt has relinquished the full-time appointments which he held as Vice-Controller of Communications Equipment under the Ministry of Aircraft Production and Scientific Adviser on Telecommunications under the Air Ministry. Sir Robert is forming a private company, but he will also continue to devote part of his time to consultant work for the Government, and will act as Scientific Adviser on Telecommunications to the Ministries.

### Mr. C. F. Trippe Retires

Mr. C. F. Trippe, M.I.E.E., well known in the radio, communications and cinema world, retired from the B.T.H. Company on December 31, 1946. He joined the company in 1927 as manager of sound reproducer sales, and continued in that capacity until September, 1945.

### Mr. W. O. Heyne

The resignation is announced of Mr. W. O. Heyne, joint managing director of the Plessey Co., Ltd. Mr. B. G. W. Attwood, B.Sc, has been appointed a director of the company.

### Professor G. W. O. Howe

Professor G. W. O. Howe was presented with a cheque for £200 on his retirement from the James Watt Chair of Electrical Engineering in the University of Glasgow. Professor Howe has handed the gift to the Principal of the University for the endowment of a prize for the most outstanding graduate in electrical engineering.

### Technical Advisory Bureau

A Technical Advisory Bureau has been formed by Mr. J. Mort, who until recently was with the Cooper Manufacturing Company. Mr. Mort is enlisting the services of a number of specialists in various branches of the radio and electronics industries who will do consulting work in their spare time, and he will act as agent between those requiring the information and those supplying it. In this way it is hoped to provide a source of information for radio enthusiasts with limited knowledge and for small concerns unable to afford a full-time technical staff. The Technical Advisory Bureau will operate from 42 Barn Lane, Golborne, near Warrington.

### R.G.D.

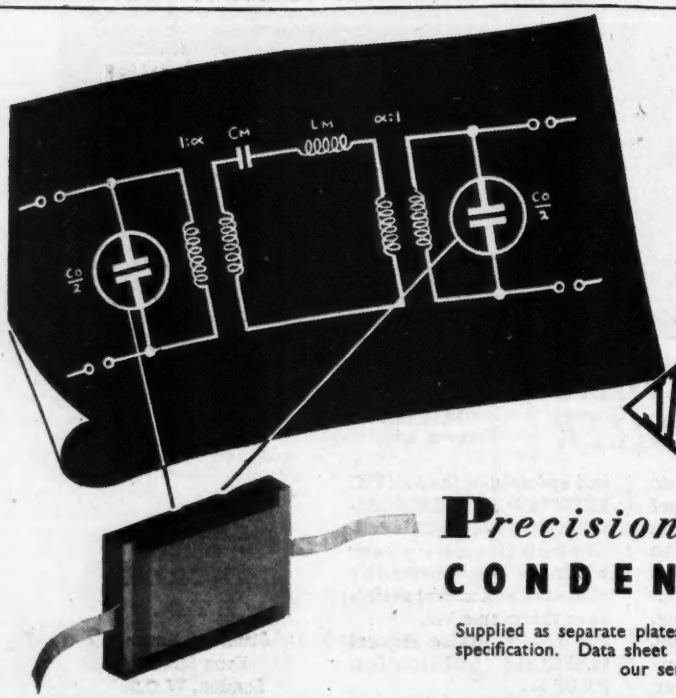
Showrooms and a dealer's service depot have been opened in Birmingham by the Radio Gramophone Development Company, Ltd., at 187 Corporation Street, Birmingham, 4. Mr. H. Burbridge has been appointed as acting manager.

### Chance-Londex, Limited

A new company, Chance-Londex, Limited, with a capital of £10,000, has been formed to manufacture, market and service battery-operated navigational and marine lights, fog signals, loudspeakers, radio location apparatus, etc.

### Radio at the Glasgow Exhibition

In the January issue of ELECTRONIC ENGINEERING (page 29) the marine equipment of Coastal Radio, Ltd., was described as a "radio telephone installation with visual alignment indicator." The visual alignment indicator, is, of course, a separate instrument marketed by this firm for lining-up of I.F. stages of superheterodyne receivers. The equipment was exhibited by Land, Speight and Co., 73 Robertson Street, Glasgow, C.2.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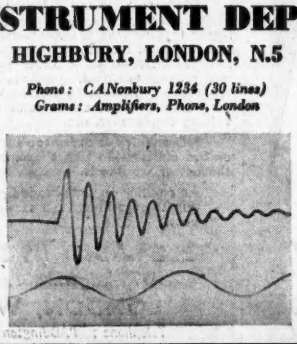

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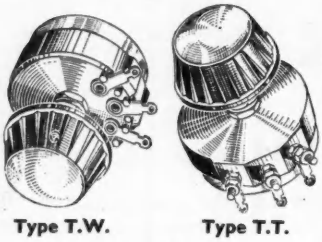

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## SITUATIONS VACANT

**ENGINEER** required by large firm in London area for design and development work on fractional horse power motors. Previous experience essential. A degree in electrical engineering is desirable. Write giving full details of experience and qualifications, also salary required, to Box 925, "Elec. Engg."

**PHYSICISTS REQUIRED** by firm in London area for research and development division. An honours degree in physics is essential and some previous research experience is desirable. Applicants should write stating age and experience to Box 944, "Elec. Engg."

**A FIRM IN LONDON** requires communication engineer with considerable experience of radio circuit design especially on aircraft equipment and miniaturisation. Good basic training and subsequent industrial experience essential. Post will be responsible one with very interesting prospects for right man. Initial salary up to £850 per annum. Write full details of education, qualifications and experience to Box 922, "Elec. Engg."

**AN ENGINEER** or Physicist required to carry out work of optical, magnetic and other problems associated with television. Must have degree in physics and knowledge of electronics is desirable. Aged 20–30. Write giving age, salary and full particulars, etc., to Box. M.1197, A.K. Advtg. 212a, Shaftesbury Avenue, W.C. 2.

**CHIEF RESEARCH ENGINEER** required by established company of repute, manufacturing deaf aids and acoustic equipment. Experience of circuit design, audio-oscillators, acoustic measuring instruments. Excellent laboratory facilities available in modern factory, W. London. Salary £650–£800 with expansion. Only first-class men should apply stating age and full experience. Box 954, "Elec. Engg."

**SENIOR RADIO ENGINEER** required for laboratory of well known firm in London area. Required for the development of commercial radio for Home and Export markets. Applicants must have ideas and initiative. A good salary and position for the right man. Box 955, "Elec. Engg."

**LABORATORY ASSISTANT** required immediately by manufacturers of Mercury Vapour Discharge appliances. Experience in electronics an advantage. Detailed application to Box 956, "Elec. Engg."

**SENIOR ENGINEER** required in South East London district, to take charge of design and development of electronic equipment. Applicants should possess a good Degree and have had extensive experience in this class of work. Salary required, age and full particulars of experience, etc., should be included in applications, which should be addressed to Box 957, "Elec. Engg."

**ENGINEERS** with experience of design of electronic test equipment required by large London firm. Previous experience in the design of test equipment for radio or radio components industry is essential. Reply stating full details of technical qualifications, experience, age and salary required to Box 953, "Elec. Engg."

**LARGE LONDON** firm requires engineer to take charge of electrical standards laboratory. Previous experience in A.C. and D.C. bridge techniques, meter standardising and frequency of measurement is essential. Reply stating full details of technical qualifications, experience, age and salary required to Box 952, "Elec. Engg."

**TELEVISION ENGINEER.** Applications are invited by a firm 30 miles from London for the position of Television Engineer. Good up-to-date knowledge of design and development essential. Consideration will be given to a qualified television engineer at present an assistant who has the qualifications to take charge of department. Box 963, "Elec. Engg."

## CLASSIFIED ANNOUNCEMENTS (CONT.)

**ENGINEERS** required for research and development department of a firm in the London area. Previous experience on the development of electronic components necessary. Applicants should write stating age and experience to Box 943, "Elec. Engg."

**R. F. EQUIPMENT, LTD.,** has vacancies in their Radio Development Laboratories for: (1) Engineer to carry through to mass production coil designs to requirements of receiver design department. Capable of working to general guidance and controlling non-technical assistants. (2) Engineer with experience in testing of radio receivers for testing of prototype models and also general development work. Write Personnel Manager, R.F. Equipment, Ltd., Langley Park, Nr. Slough, Bucks, stating age, experience and salary required.

**VACANCY EXISTS** for a research and development engineer, age between 20 and 30, on electrical and communications measurements work. Applicant should be of engineering degree standard and have a sound knowledge of workshop practice and laboratory measuring equipment. Salary approx. £400 p.a. according to qualifications. Write in first instance, stating age, qualifications, and salary required to Personnel Manager, quoting Box 958, "Elec. Engg."

**TELECOMMUNICATIONS ENGINEER** required by large firm in the London area for the design and development of radio frequency testing equipment for telephone and television cables. Applicants should possess an Honours Degree in engineering or physics and have had at least three years experience on comparable work. Salary according to qualifications and experience. Apply Box M.1079, A.K. Advtg., 212a, Shaftesbury Avenue, W.C.2.

**ENGINEER** required to assist in organisation and pre-production of complex electro-medical and other electronic equipment. Good general engineering training with experience of small quantity production is essential, with some basic knowledge and experience of electronic equipment. Write for details to Personnel Manager, The Edison Swan Electric Co., Ltd., Ponders End, Enfield, Middlessx.

**DESIGN ENGINEER** for domestic receivers. Radio engineer required for a factory approximately 30 miles S.W. London. Must be capable of designing a receiver to prototype stage without close supervision. State age, practical and theoretical experience, salary required and when free. Box 964, "Elec. Engg."

**TESTER.** Radio testers required for manufacturers approximately 30 miles S.W. London. Good prospects for workers with initiative. Box 965, "Elec. Engg."

**SENIOR ENGINEER** required for laboratory development work on line transmission equipment. Honours degree and experience with carrier current telephone equipment essential. Salary in accordance with qualifications and experience. Apply to Telecommunications Department, Ref. 235, Siemens Brothers and Co., Ltd., Woolwich, S.E.18.

**SENIOR ASSISTANT TO PATENT MANAGER.** This vacancy has now been filled and applicants to Box 923, who have not heard directly, are asked to accept this as an answer to their application with the firm's thanks.

**EFFICIENT PROGRESS CHASERS,** age 23–38, required for purchasing organisation of large radio manufacturers in South London. Experience in industry desirable. Knowledge of any of the following materials used in electrical engineering an advantage; machine tools, factory maintenance items, metals, industrial chemicals, radio components. Salary £300–£325 p.a. 5-day week. Write giving full particulars to Box No. 582, L.P.E., 110, St. Martins' Lane, W.C.2. quoting reference "J.I."

**R. F. EQUIPMENT, LTD.,** have a vacancy in their radio development laboratories for a Junior Engineer. Applicant should have a degree or equivalent qualifications with at least two years experience in industry. Initial salary £300–£450 p.a. Write stating age, qualifications, and experience to Personnel Manager, R.F. Equipment Limited, Langley, Nr. Slough, Bucks.

**PRODUCTION ENGINEER** to supervise preparation of drawings and production of electronic equipment. B.Sc. standard. Must be familiar with production and testing of electronic instruments. Salary, £750–£850 p.a. Furzehill Laboratories, Boreham Wood, Herts.

**PRACTICAL PRODUCTION** Engineer who can get results for small transformer works. Mechanical and electrical competance in theory and modern practise essential. Seekers of comfy executive position please abstain, as we require a live knowledgeable, hard working, "go-getter" type with plenty of initiative who will be paid accordingly. Please phone SPE 8085, A. C. Electrical Co., Elm Terrace, Hermitage Lane, N.W.2.

**DEVELOPMENT ENGINEER,** preferably with knowledge of servo technique, to take charge of laboratory engaged on design of industrial electronic equipment. Salary £800–£900 p.a. Furzehill Laboratories, Boreham Wood, Herts.

**REQUIRED CHIEF ELECTRICAL** Radio Engineer with initiative and creative ideas, to take complete control of radio research laboratory, drawing office and model development shops engaged in the design and development of radio receiver and allied apparatus and electrical domestic appliances. Location—London area. Write, stating technical qualifications, practical experience and salary required to Box 967, "Elec. Engg."

**REQUIRED**—Test Engineer with knowledge of high power high frequency valve generators. Box 968, "Elec. Engg."

**RESEARCH AND TEST** Assistants required by manufacturers of high vacuum equipment covering electronic, instrument, engineering and physical apparatus. Higher National Certficate or Intermediate in engineering or physics and experience in similar work desirable. Salary according to age, experience and qualifications. Good opportunities for first class workers; 5-day week and superannuation scheme in operation. Apply in writing only with full details to, W. Edwards and Co., (London), Ltd., Kangley Bridge Road, Lower Sydenham, London, S.E.26.

**PHYSICIST** required for experimental work by large engineering company in London area, honours degree in physics or applied mathematics or similar qualifications essential. State full particulars of qualifications, age and salary required to Box 969, "Elec. Engg."

**DRAUGHTSMEN.** Senior and junior, experienced in the preparation of drawings of electro-mechanical apparatus, required by large light engineering firm in London area. Reply stating details of experience, age and salary required to Box 970, "Elec. Engg."

**B.Sc.CHEM.** required to work in close co-operation with research team on materials for vacuum tubes. The work would be to cover patent, trade and technical literature from the point of view of possibilities of new materials, etc. Appreciation of vacuum tube physics an advantage. S. W. London area. Write Box 641, L.P.E., 110, St. Martins' Lane, W.C.2. Quote Ref: M.I. 38.

**GRADUATE PHYSICIST** under 30 years, required to devise and carry out electrical tests, as member of research team on electrical properties of solids. S.W. London area. Write Box 625, L.P.E., 110, St. Martin's Lane, W.C.2. Quote Ref: M.I. 35.

**APPLICATIONS** are invited for the position of electrical and mechanical engineer by company engaged in research and development of wide range of light electrical, electronic and mechanical devices within 30 miles of London. It is essential that the applicant has experience of production methods and mechanical design, particularly radio equipment. Qualifications should include an engineering degree or equivalent. Used to control of technical and similar staff. Salary according to age, qualifications and experience, approx: £800/900. Box. 972, "Elec. Engg."

**TECHNICAL ASSISTANTS** for circuit development in electronic application lab., of West London aero-engine manufacturers. Considerable industrial experience of a kindred nature essential. Also Junior for testing and assembly of prototype equipment. Full details, age, qualifications, experience, salary required, etc., to Box No. A.B.329, c/o Central News, Ltd., 17, Moorgate, E.C.2.

### SITUATIONS WANTED

**CHIEF ENGINEER** with leading hearing aid manufacturers seeks executive position in electronic field with wider scope for setting up research, production and service departments on sound engineering lines. Ex.-R.A.F. F/Lt. Radar laterly directly responsible for all British development on M.I.T. designed, American built, G.C.A. equipment. Extensive pre-war laboratory experience in radio, television and measuring instrument field. Box 962, "Elec. Engg."

**ENGINEER,** aged 24, graduated, I.E.E. with industrial experience in electronics since 1939, seeks post with reputable firm, preferably in N.W. London area. Box 959, "Elec. Engg."

**QUALIFIED ENGINEER,** 7 years experience, receiver and instrument design, component manufacture and testing for mass production, seeks responsible position. Box 951, "Elec. Engg."

**ELECTRONIC ENGINEER,** Assoc. Brit. I.R.E., age 28, requires responsible position in charge of or as designer. Experience, test gears, coils, receivers, etc. London area. Box 966, "Elec. Engg."

**ATTENTION, EXPORT MANAGER.** Swiss Electr. Engineer available soon. 16 years in power and communications engineering (CCIF, CMI, CISPR, CIGRE). 10 last years in development and selling of electronic equipment with pioneering firm; excellent relations with leading engineers in Europe. Speaking English, French, German, and good knowledges in Spanish, Italian and Portuguese. Particularly interested in industrial applications or to assist factory representative for trade in Europe. Kindly ask details and references: my telegraphic short-address: "Telectronic Zurich."

**WELL EDUCATED** Air Force Officer, M.Sc., adaptable, with some experience radar, also high voltage and heavy engineering. Due for release March, would like to hear from electronic firms in London area. Research preferred. Box 971, "Elec. Engg."

### WANTED

**WE OFFER** cash for good modern Communication and all-wave Receivers.—A.C.S. Radio, 44, Widmore Road, Bromley.

**WANTED.** Any quantity up to 2 cwts. of Litz Wire 27/48 S.W.G. Double silk covered. Will anyone who can supply, kindly write Stratton and Co., Eddystone Works, Alvechurch Road, West Heath, Birmingham 31.

**REQUIRED URGENTLY,** Cambridge test set or sub-standard voltmeter, ammeter, wattmeter and vibration galvanometer, 50 cycle operation. State details and prices. Meico, Ltd., Congleton.


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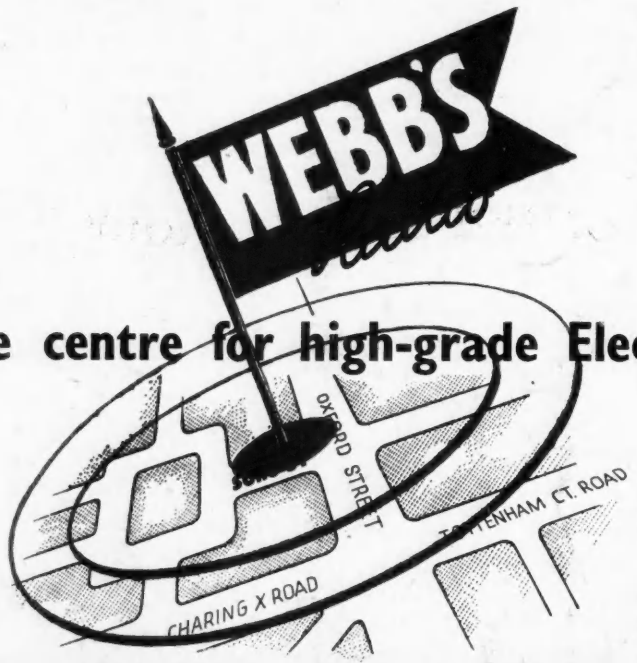


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The moving-coil pick-up has come to stay—the general clarity of reproduction is unchallenged. We have two representative makes in stock :—

**LEXINGTON "DE LUXE" Model**
Automatic insertion and rejection of sapphire needles. Needle pressure approximately ½ oz. Price (including Purchase Tax) .. .. **£6 5 0**

**LEXINGTON "JUNIOR" Model**
Similar construction to the "De Luxe," but without mounting base and automatic needle device. Uses commercial steel needles; easily replaced. Price **£3 18 9**

**Lexington Sapphires, 15/3. Input Transformer in Mu-metal box, 30/2**

**WILKINS & WRIGHT, Type "N"**
Uses easily changed commercial hard-steel needles, playing approximately 20 records. Needle pressure adjustable from ¼ oz. to 1 oz. Complete with coupling transformer and equalizer in screened case, arm rest, instructions and fixing screws. Price (including Purchase Tax) .. .. .. .. **£7 0 7**

**Wilkins & Wright "Scratch" Filter**
Not merely a "top" tone control, but a low-pass filter cutting above 8.5 Kc/s. Price (including Purchase Tax) **£2 11 4**

**Wilkins & Wright Steel Needles**
In handy container with 20 needles. Price .. .. .. .. **5/6**

**GOODMAN'S 12-IN. P.M.**
A heavy duty reproducer capable of excellent quality, speech-coil 15 ohms. Price .. .. .. .. **£6 15 0**

**WHARFEDALE W. 10/C.S.**
A new 10 in. P.M. reproducer of interesting design and excellent fidelity. Bass resonance below 60 c/s and top effective to 18,000 c/s. Price .. **£7 0 0**

**CELESTION RANGE OF P.M.**
Speakers, usually available—2½ in., **27/0**; 3½ in., **29/6**; 8 in., **30/0**

**LONDEX AERIAL RELAYS**
(6 v. A.C. operated) **type AECO4** Double-pole changeover contacts for up to 4 amps. Base size, 3 in. by 3 in. Price .. .. .. .. **£2 17 6**

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**CO-AXIAL CABLE**
0.54 in. dia. polythene insulation braided copper with P.V.C. outer covering. Impedance 80 ohms.
Price, per yd. **1/6**

**DURALUMIN TUBE** Outside dia., ⅜ in., 8 ft. 6 in. length for 5- and 10-meter work, **4/6**; 10 ft. 6 in. length for Television, etc., **5/6**
(NOTE : *Callers only for this tube. Cannot be despatched.*)

**WEBB'S RADIO FEEDER**
Ready built in lengths of 50 and 35 feet. Spacing 3½ in. with 18-gauge wire. Polythene spreaders securely moulded into wire every 20 inches, light and rigid construction. Supplied on drums ready for winding off, and immediate use.
Per 50 ft. drum .. .. **£1 17 6**
Per 35-ft. drum .. .. **£1 6 3**
(Packing and despatch **2/6** extra.)

**EDDYSTONE MICRODENSERS**

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| 1094. | 20 P.F., 3,500 v. .. .. .. | 6/0 |
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| 1130. | 100 P.F., 1,000 v. .. .. .. | 7/11 |
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**STANDARD GANGED Condensers**
(all have ceramic insulation)

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**MINIATURE 2-gang Condensers**
especially applicable for H.F. & V.H.F. work (S.L.C.
Panel mountings, 1⅛ by 1½ by 1⅛ in. deep, plus spindle.
44 plus 44 P.F. .. **10/3** 18 plus 18 P.F. .. **7/6**
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